BELL TELEPHONE QUARTERLY

VOL. XV APRIL, 1936

THE BELL SYSTEM FIGHTS THE FLOODS

FURTHER BY-PRODUCTS OF TELEPHONE RESEARCH

BEHIND THE SCENES IN A CENTRAL OFFICE

SOME EARLY TELEPHONE PROPHECIES

AMERICAN TELEPHONE & TELEGRAPH CO. • NEW YORK

BELL TELEPHONE QUARTERLY

A Medium of Suggestion and a Record of Progress

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TRUCKS MOBILIZE MATERIALS AND MEN AT THE HOLYOKE-SOUTH HADLEY (MASS.) BRIDGE.

The Bell System Fights the Floods

Editor's Note:

The writer of this article has twice before contributed to the BELL TELEPHONE QUARTERLY *graphic accounts of the Bell System's prompt and effective functioning, because of its integrated organizations, in meeting the challenge of wide-spread disasters. The first of these articles was "Mobilizing for the Fight against Sleet" which appeared in the January, 1925, issue and described the effects of the storm that swept from the Gulf to the Great Lakes in the winter of 1924. The second was "The Telephone's Part in the Mississippi Flood Fight" and appeared in the issue for July, 1927. The issues for April and July, 1934 also recounted the effective mobilization of the system's resources in local disasters as demonstrated in connection with destructive fires at Anderson, Indiana and Birmingham, Alabama.*

MELTING snow. Spring rains. Mountain rills rising, to become streams; streams swollen into rivers; rivers transformed into rushing torrents, carrying death and destruction in their wake. The normal relationships of business and social life disrupted. A city of half a million and a hamlet of half a dozen houses attacked by forces which strike at the one and the other with tragic impartiality. Floods.

Such was the foe which, on a front extending from Maine to the valley of the Ohio, the Bell System was called upon to fight during turbulent days and weeks in the middle of March, 1936. The word *fight* is used advisedly, for here was a battle without precedent in the history of the telephone, in the issues it involved, as in the extent of the terrain over which it was waged.

The Bell System, in its long history, has faced many public emergencies. But floods are not like other catastrophes, and this was not like other floods. Fire may destroy a central office, silencing the telephones which it serves; hurricane or tornado may cut a swath of destruction across a state; a cloud-

burst may inundate a village or imperil a single city. But such catastrophes, as contrasted with this, may be looked upon as localized; here was one against which war must be waged at a hundred points simultaneously.

Floods—and floods covering wide areas in particular—are unique among public emergencies in the extent to which they disturb the human contacts which it is the function of all communication facilities to provide. Rising waters place a premium on the maintenance of telephone service, which reaches into homes, offices, factories, farms, tying them together and giving them access to physicians, hospitals, the police, the fire department and other public or semi-public agencies upon which the protection of life and property depends.

Local telephone service becomes, in such an emergency, the nervous system of an organization which must swiftly be set up to handle relief problems, to safeguard health, to prevent further destruction. Long Distance service performs the same functions, on a wider scale; provides the means of allaying the anxiety of friends or relatives of those who are within the flooded area; permits the mobilization of a nation's resources to aid the suffering or succor the needy. It is no mere catchword that the men and women of the telephone service have coined when they say, in such emergencies: "The message *must* go through!"

It must, and they know it. And they know the difficulties under which they are to work in order that it may go through. They know that, from the very nature of most of the apparatus which provides telephone service, this apparatus cannot function properly, or at all, when submerged. They know what will happen to switchboards and countless other things if the waters rise high enough. They have no illusions about what lies before them when they begin a war against floods.

Most of the credit for the victorious battle in March with rising water should properly be given to the men and women whose devotion to duty has provided some of the highlights of

a drama enacted on a stage as wide as a dozen states. Some of it should go, however, to the vision and foresight of men who years ago laid the foundation for an integrated, unified telephone system which not only can meet the daily needs of a nation for direct, personal communication, but can mobilize men and materials for the meeting of these needs when they are augmented by great public emergencies.

The Waters Rise

Thanks to this integrated service, telephone people were as well prepared as men could be to meet the crisis with which they were confronted as the flood waters swept through scores of hamlets, villages and cities. In Johnstown, Pa., there were recreated scenes suggestive of the disaster of 1889—all save the loss of life. Rising waters rolled, too, into Springfield and Holyoke, Mass., moved sullenly down the valley of the Connecticut and inundated Hartford, and on to Long Island Sound. The Susquehanna and the Delaware rose above their banks; the Potomac menaced Washington itself. Water stood deep in the streets of Wheeling. Pittsburgh, Williamsport, Wilkes-Barre—in a score or more of Pennsylvania communities, as in scores more in New England, in Southwestern New York, in Ohio, Maryland, Virginia and West Virginia, the battle was on.

The full story of this struggle cannot be written. All that it is here possible to do is to touch on certain well defined aspects of the problem of providing telephone service under conditions such as these, and to see how these problems within a problem were solved.

The first of these problems, obviously, was that of maintaining the physical facilities required for the rendering of telephone service. When these fail, the devoted loyalty of operators is unavailing. Circuits had to be kept intact or, if broken, had to be mended. Or if they could not be restored to service, substitutes had to be found for them. Switchboards

had to be protected from water as long as possible, and if the water got to them, other switchboards had to be rushed into service elsewhere to take their places. Isolated telephone buildings had to be reached, food carried in for those who were there, doing duty on the firing line. Supplies of telephone equipment had to be rushed to areas where apparatus had been rendered useless. In literally scores of places these things, and many more, were being done simultaneously, by a dogged, determined army that would not admit defeat.

Reports from the Front

Over the teletype at the headquarters of the Bell Telephone Company of Pennsylvania, at Philadelphia, clicked terse messages conveying vital reports and orders and also such messages as this, describing the progress of the battle:

> SUNBURY, 3:45 P.M. Central office men are removing ringing machine, moving parts to upper floor of building and reassembling them. All doors and windows on first floor barricaded and sealed to keep out flood. Operators tired but cheerful. We're here to stay.

Or this, from Williamsport, where the struggle on another sector was becoming acute:

> Water still coming after us. Local service still operating. Two feet more and the toll switchboard will go under. There's nothing for us to do but wait and hope.

Or this:

> LOCK HAVEN, 8:45 A.M.—Six feet of water in main streets. No regular power available. Have been using automobile batteries to run switchboard for several hours. Don't worry. We can hold out as long as equipment lasts.

Or this, from Pittsburgh, on the morning of March 19:

> All emergency equipment that we can beg, borrow or buy is being concentrated. Continued transportation difficulty in get-

ting heavy stuff like emergency charging units to the stricken points.

All hands on deck everywhere. Operating forces have gotten through to their offices somehow. The men are fine. The women are magnificent!

Over teletypes in Boston and New Haven and New York and Washington and Cleveland similar bulletins were being received, almost in an unbroken flow, save when telephone people on the firing line were too busy doing things to stop to tell what they had done.

In Western Pennsylvania, the menace to telephone plant was complicated by other evidence that when Nature turns outlaw, she never does it by halves. Twenty-four hours before flood waters began to reach dangerous stages, the entire northwestern portion of the state was swept by a serious storm. As if opening her battle against the telephone forces with an artillery barrage, Nature hurled a salvo of sleet. Ice freezing on wires and crossarms, accompanied by high winds, snapped off more than 800 poles between sunset and sunrise, and put 175 toll circuits out of service. With the service-restoration problem arising from this wholesole destruction of plant, the telephone men of Pennsylvania were struggling when the floods struck, on a dozen fronts at once.

In Central and Western New York, the telephone forces had to fight not only floods and sleet, but snow. In and around Buffalo the snowfall was one of the heaviest of the winter, while sleet swept the eastern end of the central portion of the state. The Susquehanna and Chenango rose and swept down upon Binghamton. Elmira plant men had a battle on their hands with both flood and sleet. In dozens of other towns, telephone men and women found themselves facing a combination of foes which called for all they had of courage, fortitude, endurance and resourcefulness.

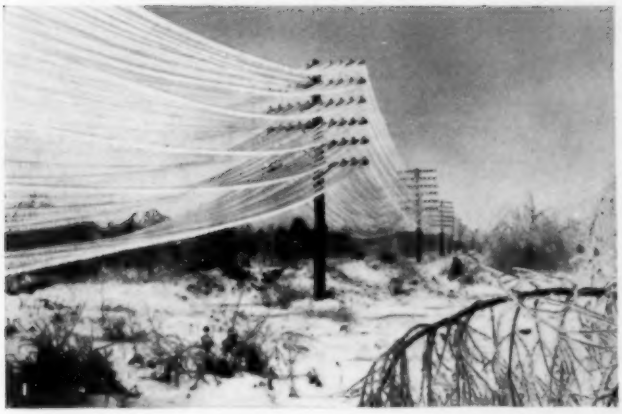
After the peak of the flood on the Ohio had done its worst in Western Pennsylvania, it swept on down the valley to

Wheeling, where plant forces of the Chesapeake and Potomac Telephone Company were waiting for it, ready to fight it to a standstill. Every resource of plant or personnel which they had at their command was thrown into the struggle. Cable gangs were called in from other points in West Virginia to speed up the work of restoration as soon as the recession of the waters made this work possible. Meanwhile, as elsewhere, sandbags were piled around entrances to telephone buildings, doors were barred and sealed to prevent the entrance of the flood waters to lower floors, pumps were started and kept going without pause until the emergency had passed, all to the end that equipment might be kept in operation.

In Virginia and Maryland, rivers rose far above normal stages. The James was nearly twenty-five feet above the mean level at Lynchburg. There was high water at Richmond. The Shenandoah Valley felt the force of the rising waters.

Wherever the battle was being fought, the first concern of telephone men and women was to keep open the lines of communication to the police and fire departments, the Red Cross, the hospitals, the WPA relief stations, and the offices and homes of physicians.

In a few cases it was necessary, when the flood was at its peak, to restrict telephone service to these essential points and other emergency stations in order to conserve current from storage batteries which had been cut off from their usual source of power. Indeed the loss of current in these and certain other cases, occasioned by the flooding of the power company generating stations, was one of the serious problems which telephone men had to face. It became necessary quickly to set up emergency power equipment and the shifting of equipment of this character and of other supplies from one area to another, affords a striking illustration of the advantages of an integrated system which makes this mobilization of materials possible.



1. *Severe sleet storms swept Northwestern Pennsylvania just prior to the floods.*

2. *Ice-jammed Kennebec River, Richmond, Me.*

3. *Holyoke-South Hadley, Mass., bridge. (See frontispiece. Note the broken cable at lower left corner.)*

4. *Business office at Hartford after water had partly receded.*

5. *Barn resting on a telephone cable in Connecticut.*

6. *Up to cross arms of an A. T. & T. toll lead, Ohio.*

7. *Water pouring into basement at Hartford.*

8. *High water mark at entrance of Sterling office, Pittsburgh.*

9. *Telephone office at Bridgeport, O., is on second floor of corner building.*

Through night hours, trucks rolled along Connecticut roads converging on Hartford with their burdens of emergency equipment which meant life to a city's telephone service. Powerful engine-generators were brought from as far away as cities in New Jersey and from west of Syracuse, New York.

In the rest of New England in the states where the New England Telephone and Telegraph Company operates and in upstate territory of the New York Telephone Company, similar scenes were enacted. Wherever power failures were experienced or seriously threatened, engine-generators were moved in either from other offices or from warehouses.

On Pennsylvania roads leading toward Pittsburgh and other stricken cities, other trucks, bearing similar burdens, were enacting similar roles in the drama of the Bell System's battle to keep its service intact. Heavily laden, hampered by roads which at places were covered with water or which had turned to mud, they went rolling doggedly along—caissons in the field artillery of a far-flung peacetime battle.

The Service of Supply

One of the dramatic chapters of the history of this war against rising waters, if this history is ever written, will be that which recounts the exploits of the men of the Western Electric Company in maintaining the "service of supply" which helped to make victory possible.

A great battle is a test, not alone of the stamina and the spirit of those who engage in it, but of the strategy of those who have planned it. To such a dual test the supply system provided by the Western Electric Company was subjected in this most acute and most widespread communication crisis with which it had ever been confronted. That it stood this test is apparent from the fact that, faced by the necessity of making the largest emergency shipments of telephone supplies and equipment in the history of the telephone in America, it made these shipments with a speed and an efficiency which have never been surpassed.

In order to meet such situations as this, as well as to handle efficiently the demands of everyday telephone construction and maintenance, the Western Electric Company maintains, at strategic points throughout the country, warehouses well stocked with stores of supplies and equipment which may be drawn on at a moment's notice. It had made preparation for the floods of this Spring, for conditions had indicated, in advance, that there was likely to be high water. Special stores of emergency supplies were in readiness. The first flood warnings were the signal to the crews of these warehouses, and to those of the company's three principal factories at Chicago, Baltimore and Kearny, N. J., to hold themselves in readiness for immediate action. Directed from headquarters at 195 Broadway, New York, all locations likely to be involved in the emergency were put on twenty-four hour duty. At Philadelphia, New York, Brooklyn, Washington, Boston, Newark, New Haven, and at Pittsburgh—itself in the center of one of the most serious of the battle sectors—Western Electric warehouses became scenes of intense activity, while those as distant as Atlanta, Detroit, Chicago and Cleveland held themselves in readiness and dispatched material as called upon.

From these depots of the Bell System's "service of supply," tons of material, made up of literally hundreds of items, were shipped in an unbroken stream during the days and nights when the emergency was at its height. In warehouse and factory alike crews worked in continuous shifts and in some of the factories, during this peak of demand, normal output was more than doubled. Engineering, warehousing, service and traffic experts wheeled into action, bending every effort to expedite the movement of supplies and equipment to the point where they were needed.

As purchasing department for the Bell System, the Western Electric Company obtains from outside manufacturers large quantities of supplies which it does not itself manufacture.

Many of these were required to meet emergency demands in the flooded areas. These concerns were notified to hold themselves in readiness, and when the orders began to roll in, they turned to and contributed their part to the winning of this war against rising waters.

Enormous Emergency Shipments

During the seven days when the floods were at their most critical stage, the supplies shipped to telephone companies in the flooded areas reached astounding proportions. Among some of the major quantities were more than 50,000,000 conductor feet of rubber-covered wire; nearly 24,000 telephones; 750,000 pounds of copper line wire; 200,000 pounds of pole line hardware; twenty-three sections of central office switchboard and scores of private branch exchange boards. Cable, conduit, crossarms, telephone poles or rubber boots—whatever was needed, when and where it was needed, was sent on its way from warehouse or factory without a moment's unnecessary delay.

At noon, Monday, March 23, Boston advised Western Electric headquarters at New York that it needed at once twelve P.B.X. boards of the 750–A type, in addition to ten already ordered. Headquarters canvassed nearby Western Electric warehouses. Simultaneously, it obtained a five-ton padded furniture truck on which the boards could be carried without first packing them, thus saving valuable time, and by 5:45 P.M. it was on its way with the twelve boards and five others, reaching Boston at nine o'clock the next morning.

From the morning of March 18 up to March 25, the Point Breeze plant shipped more than 600 tons of emergency material into various flood areas. Late on March 19, Pittsburgh placed an order with this plant for special armored submarine cable. This had to be manufactured, from the ground up. The cable left the plant at noon, March 22. The reel, weighing 14,000

pounds, was so wide that a special truck was required to accommodate it.

The history of the Bell System's service of supply contains few more inspiring chapters than that which tells of the stubborn battle of the crew of the Western Electric Company's warehouse in Pittsburgh against the waters which swirled around and through this outpost on the firing line in the battle against the floods. A number of warehousing and service experts were rushed to Pittsburgh from other points by airplane, and with their aid the regular crew fought desperately to keep the service of supply from failing. Finally the rising waters cut off power, heat and light and completely isolated the building. After thirty-six hours of continuous duty, the crew were obliged to retreat temporarily, leaving the building in a rowboat from a second-story window. But the retreat was only temporary. The next day a crew of seventy made their way back and again began making shipments—through the same second-story windows, using boats as their means of transport.

The Transportation Problem

One of the major problems faced by the service of supply was that of transportation—a further illustration of the difficulty of dealing with flood conditions affecting wide areas. At the very moment when rapid transport became indispensable, transportation facilities were disrupted. Railways were crippled; paved highways were under water and dirt roads so softened by rains that they afforded no practical detours for routes made impassable by the floods; bridges were out; many air transport fields were transformed into inland lakes. To meet such emergencies as this, as well as to provide an efficient method of handling normal transport problems, the Western Electric Company maintains a staff of traffic experts. When the first demands for the mobilization of men and materials began to come in to headquarters, this staff of highly specialized transportation experts went into action. Reports on highway con-

ditions and railroad schedules were collected; the best available methods of transportation and the shortest possible routes were selected; every possible method of carrying men and materials, from where they were to where they were needed, was brought into action.

Railway Fliers Carry Freight

There was one case in which the Broadway Limited was held five minutes in order that an engineer of the Western Electric factory at Hawthorne, near Chicago, could carry with him, as excess baggage, a shipment of apparatus which had to make the first train into Pittsburgh. Crack railway fliers, such as the Spirit of St. Louis, pulled out of stations with freight cars sandwiched in between their luxuriously appointed sleepers or coaches. In five days 218,300 pounds of telephone apparatus was delivered to the flooded areas on passenger trains.

So, on a score of sectors, the telephone service of supply continued to function. Materials by tons were moved up to the firing line and men by hundreds were mobilized to assist in the installation of these materials where they were most needed.

This mobilization of the Bell System's manpower in a crisis presented by a great public emergency is, incidentally, a convincing demonstration of the value of "One System, One Policy, Universal Service." By reason of the standardization of equipment design and of construction and maintenance practices, a Bell System plant man, anywhere, can be moved to any point at which he may be needed, at a moment's notice and will find, when he arrives, that he is as thoroughly familiar with the job which he must do as if he were doing it at home.

Mobilization of Manpower

And moved they were, by dozens and scores, these men of the telephone service, to help their fellows on the firing line fight the floods which had become their common enemy. From Philadelphia, early in the opening stages of the battle which

was fought over the western part of Pennsylvania, came this terse teletype report:

> Twenty-five line crews, with full equipment and motor vehicles, on way from here to Harrisburg. From there they will go to stricken districts as fast as possible.

Elsewhere, in New England, in New York, in Ohio and down in the valley of the rapidly rising Potomac, other crews of reserves were being mobilized and moved up to the front. They were sent into the Pittsburgh area from as far east as New Jersey, from Ohio and from as far west as Detroit—they could as easily have been sent from California if there had been means of carrying them to the flood areas swiftly enough to make such a mobilization practical.

A further example of the mobilization of the Bell System's man power to meet emergency conditions is afforded by the contributions of members of the General Staff of the American Telephone and Telegraph Company and of the Bell Telephone Laboratories. At Pittsburgh, Williamsport, Hartford and other points, these technical experts were quickly on the ground and assisting on many urgent engineering and operating problems. For example, important decisions had to be reached on such matters as to whether apparatus which had been submerged could be made to function properly if dried out or whether new equipment should be installed. Also technical advice was needed as to the best methods to be followed in restoring such equipment, where practicable, to working conditions. Assistance was likewise rendered in some cases in connection with emergency power facilities and testing arrangements.

Long Lines in Action

While crews of the Bell System operating companies in the territories affected by the floods were struggling to maintain local service, and toll service within their own areas, other crews

of the Long Lines Department of the American Telephone and Telegraph Company were putting up an equally courageous and equally successful battle to keep long distance lines in operation. Even while the flood waters were at or near their peak in many localities, these Long Lines gangs succeeded in restoring ninety-six per cent of the long distance circuits which would normally have been in service. During the whole period of the flood, Williamsport, Pa., was the only city of any considerable size which was totally cut off from voice communication with the outside world, and long distance circuits into that city were operating by Saturday, March 21.

Long Lines men working in boats repaired the Albany-Springfield cable which was carried away by ice and debris when the flood waters rose to record heights at South Hadley Falls, Mass. Incongruously enough, at almost the same time, repair gangs at Hartford were also working in boats, but inside the telephone building, to repair a long distance cable which had gone out of service.

Long Lines test boards everywhere became scenes of intense activity. The long distance traffic control bureau in New York, during the six days when flood conditions were most serious, issued about 1000 "patch orders" by way of providing substitutes for circuits which had been put out of service. The normal average of such orders at this bureau is about ten a day. In Cleveland, O., where more than four or five "patch orders" a day would be looked upon as exceptional, a hundred or more were issued during the emergency period, and at Chicago the increase was correspondingly high.

Cable Network Proves Value

Tested by the rising waters, along with the endurance and fortitude of Bell System's personnel and the reliability of its plant, was the policy which has made such dependable plant available. This fact was convincingly demonstrated by the

manner in which the local and long distance telephone cable network withstood the severe conditions to which it was subjected throughout the entire flood area.

When aerial lines were torn out by rushing water or floating ice and debris, or were snapped by sleet, as scores of them were in northern Pennsylvania, long distance telephone cables continued to function. Many of them remained in service although they were submerged for days.

In several cases, even these cables were in danger of failing, due to the battering their heavy lead sheaths received from trees, ice and other floating debris. To keep the water from entering the interior of cables in which leaks were caused by these conditions, nitrogen gas, under pressure, was forced into the cables. The slow escape of this gas, through any breaks in the sheath that might be thus caused, prevented the water from entering. To meet the demand for nitrogen, containers of the gas were shipped from distant points by airplane.

Not only was the American Telephone and Telegraph Company able to maintain a high percentage of its own long distance service during the emergency, but also provided valuable assistance to the telegraph and railroad companies by furnishing them with telegraph and telephone circuits through its cable network. At the maximum, the American Company was furnishing other communication companies with a total of more than 53,000 miles of wire.

Long Distance Traffic Mounts

Long Lines traffic in many areas rose far above normal levels. At most points throughout the flood regions, double the normal number of long distance operators were on duty at the switchboards, struggling to give prompt service on the flood of emergency calls that swept through their offices. On Sunday, March 22, the Long Lines traffic at Buffalo was 118 per cent above normal; at Pittsburgh, 219 per cent; at Cleveland, 134

10. *Hartford operators hard at work at the toll board and—*

11. *Turning in for the night on cots and settees in an improvised dormitory.*

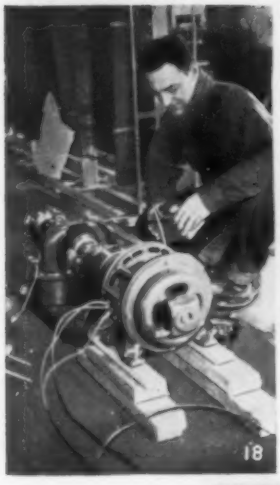
12. *A two-ton cable reel going into a Hartford window.*

13. *Catwalk bridge which saved the situation for Hartford folks.*

14. *The public made emergency long distance calls in the Pittsburgh business office by lantern light.*

15. *Power units were rushed to the flood areas from far-distant points.*

16. *The Pittsburgh "Light Brigade" goes into the flood battle.*



17. *Festoons of "twist" decked the streets of Williamsport.*

18. *A "home-made" ringing machine in Sunbury, Pa.*

19. *The test-boards at 32 Sixth Ave., New York, became battle sectors as "patch cords" helped carry the mounting traffic to and from the flooded areas.*

per cent; at Philadelphia, 67 per cent. The traffic out of New York to certain points was at times as high as 400 per cent above normal and emergency calls were so heavy that for the entire flood period the average traffic load in New York was more than fifty per cent above normal.

Emergencies such as these floods naturally tend to overload telephone facilities not only in flooded areas but in other places through increases in toll business. Plant is installed for reasonable engineering periods, so if adequate facilities are to be available for business expected within the period, there is, on the average, even under normal business conditions, a certain amount of margin over and above current needs. These margins have frequently been found helpful in time of emergency. Similarly during this flood emergency it was possible to make effective use of much of the present plant margin which is larger than usual because of the loss of business during the depression.

In Associated Companies, in the Long Lines Department, in the Western Electric Company, in the Bell Telephone Laboratories, and in headquarters at 195 Broadway, New York, the battle went on. From Maine to Michigan; from Vermont to Florida; from men filling quantity orders for rubber boots to other men shipping equipment by plane; from line crews climbing poles to scientists grinding crystals, every man was in his place, doing what he was called upon to do, and doing it as swiftly and as surely as long years of experience had taught him to do it.

But what of the women of the telephone service?

Coördinate with the problem of maintaining telephone facilities during an emergency is that of keeping them in operation, and this is a task for which a large share of the responsibility rests upon the women of the switchboard. It is almost superfluous to say that the telephone women of the flood areas responded to this responsibility with a devotion and loyalty that

were nothing less than heroic. But let us return to the teletype machine in telephone headquarters at Philadelphia, which we have already watched as it has clicked off its brief, almost matter-of-fact chronicle of what was going on along a battle front where women and men were fighting desperately to keep a vitally important communication service from failing when it was most needed.

"They Keep Right On"

From Johnstown, at eleven o'clock on the night of Tuesday, March 17, comes this message:

> Water still rising around us. Has reached stair landing just outside central office door. All ten operators still at the boards, putting through every possible call. They are magnificent. They know they are in a ticklish spot, and they keep right on. It's nearly freezing cold here. The water is moving at a terrific rate and is roaring past the office with so loud a noise that it is hard to hear the voices over the telephone.

From Williamsport, the next morning:

> Water at twenty-seven foot stage and within five feet of the level of the toll board in center of city. Traffic very heavy. Operators carrying on grand style. Ditto everybody else.

From other sectors along the battle line, from Maine to the Ohio, came similar stories of the part women were playing in this drama of the fight with rising waters—women at small, one-position boards serving hamlets or villages, who fought their battles single-handed; women who fought in groups, but not less valiantly, in the larger cities; women who remained at their posts of duty until, in some cases, the water finally won and their equipment became useless, and who only then retired from the field, to return once more at the earliest opportunity.

So one might have seen, at Hartford, a company of a hundred operators grimly plugging up connections, hour after hour, while on the ground floor men were fighting a gallant battle to

keep the water out of the equipment. Hour by hour the traffic mounted, as emergency or relief officials directed the battle to save the city from the menacing waters which filled its streets. Girls from the business offices volunteered to help carry the load at the switchboard by passing toll tickets, and in other ways gave the weary operators a chance for brief periods of rest. Cots were brought into operating rooms or rest rooms, and on these—or on tables or on anything else which could serve for a bed—the tired girls lay down to snatch what they could of rest.

In other cities and towns throughout the flood areas, similar scenes were being enacted. It is impossible, in an account of this character, to record individual names of telephone women and men who distinguished themselves, or even to list all of the localities in which telephone people did heroic service.

Getting Food to the Firing Line

But what a picture of one sector of this battle with the floods is presented by this teletypewriter message, dated from Johnstown at 8:35 A.M. on March 18:

> Thanks for the boat. Train stopped four miles from city, boat hauled balance of way. Just had food brought in—first since yesterday noon. Girls' appetites good as ever—and they appreciate the blankets.

Which suggests a brief digression. One of the problems involved in maintaining telephone service in these isolated central offices was that of getting food and other comforts into the buildings for the use of those who were doing duty on the firing line. In Johnstown, as in many other places, it was done by boat. In Hartford, a steel cable cat-walk bridge was strung across the street between the Pearl Street building and the isolated Trumbull Street building, and over this swaying bridge there moved an almost steady stream of men, women, materials and supplies. Over it were carried thousands of hot

meals and gallons upon gallons of hot coffee to satisfy the hunger and to revive the waning energies of the hundreds of men and women who were at work in the water-bound building. Girls from all departments of the telephone company volunteered as emergency members of the cafeteria force. Dozens of them washed dishes from Friday to Monday. Other sources of heat having been cut off by the rising waters, plumbers' furnaces, commandeered from the plant department, were used to boil the water for dish washing.

Throughout the flood areas, scores of operators and other girls, who were off duty, voluntarily came back to work because they knew they would be needed. Often operators made their way to central offices under difficulties which would have turned back women, or even men, with hearts less stout. One of these was a chief operator in an Ohio town, whose home was in another community, some distance away. High water swept over the highway and the interurban railway connecting the two towns. In an effort to reach her central office, the operator took one of the last of the interurban cars to attempt to make the run between the two communities. It was stopped by the flood.

Over Ice-covered Railroad Trestles

She asked if there was not some way by which she could get through. While others were turning back, she made her way over a route which took her over open fields, through snow that was knee-deep, to a railway track. Over its ice-coated rails and ties she walked, crossing several trestles beneath which rushed the swirling flood waters. At some points, the water was so high that, as she passed over these trestles, she could have dipped her feet into it. After more than a mile of such hazardous travel, she reached the central office. She and her force of six operators, augmented by three volunteers, kept at their post until the emergency had passed.

Nor was this spirit of loyalty to the public interests manifested alone by women who are now telephone employees. In every great emergency, scores of former operators offer voluntarily to return to the switchboard. So it was in the emergency which has just passed. A woman who for fifteen years was an operator at Norfolk, Va., called up telephone headquarters in Philadelphia, where she now lives with her family, to offer her services in the flood stricken areas. "I'd like to do something to help out—anything at all," she said. "If you need me, please call and I'll be ready. I'll go anywhere."

What is this thing which prompts a woman to walk ice-covered trestles in order that she may reach a place where she knows that she will be called upon for long and arduous and perhaps hazardous duty? What impels an ex-operator to volunteer to return to the switchboard—to say that she "will do anything" or "go anywhere"? When Arthur Lamare, a lineman of the New England Telephone and Telegraph Company, was swept to his death while crossing the Williams River near Bellows Falls, Vt., with three other telephone men, in order to do an emergency job, what was the motive which prompted him thus to face danger in the performance of duty?

"The Spirit of Service"

The men and women of the Bell System have come to call this "The Spirit of Service." They cannot define it. Nor can anyone else. It is not something to be described by words; it is something to be lived. It assumes concrete and understandable form only when men and women do the things which telephone people do in great emergencies because they know that for the doing of such things there is a vital human need.

And out of the Bell System's battle with the floods has come a full measure of recognition of this spirit. It is here possible to include only a few typical expressions.

On the stub of a bill returned, with a check, from a woman subscriber in Pittsburgh was written this brief but expressive sentence: "Congratulations on quick return to service, after the flood."

From this terse tribute, by an individual subscriber who wished to express her gratitude for the prompt restoration of service in her home, to much more formal expressions, the letters poured in. They came from public officials, heads of relief organizations, business executives, professional men, heads of hospitals—from all sorts and conditions of men who had, in short, seen what telephone people had done during the flood and who wished to thank them for it.

"Unbelievably Helpful"

The chairman of the Pittsburgh Chapter of the American Red Cross wrote:

> I have already told you, and I intend to repeat it on every possible occasion, the deep appreciation that the Red Cross feels for the unbelievably helpful attitude which the telephone company has taken during the recent disturbance. Specifically, however, I would like to say a word about the trouble-shooting crew which you had in the Community Fund Building since the flood started. Hardly an hour of any day passed that we did not make some request of these men, and in every instance we were met with courtesy and, what is more important, I don't think there was a time that we failed to get what we wanted from them.

Some of the letters received spoke not alone for their writers individually, but on behalf of the people of entire states. Thus the governor of New Hampshire wrote to the President of the New England Telephone and Telegraph Company:

> It is almost impossible for me to express to you the personal appreciation I feel and the appreciation I know the people of the State of New Hampshire feel for the services you gave us throughout your organization during the period of the recent disaster.

Every means at your disposal was made available that the State could better combat the disastrous sequence of events which came upon us so rapidly and with so little warning.

Your company and its employees performed a great service at a time when it was most needed. This performance saved hundreds of lives and an untold amount of property, both public and private.

It would be difficult to extend appreciation individually to each of your employees who worked at their posts during the flood. Please convey to them my deep appreciation for the services they performed and the gratitude of the people of New Hampshire whom they served so well.

Tributes in the Press

Not less outspoken in its praise of telephone service, and of the men and women who provide it, was the press. In large cities and small villages, from great dailies to struggling weeklies, the newspapers of the flooded areas, and of the nation as a whole, paid high tribute to the devotion which made possible the maintaining of a vitally important communication service. Said the Portland, Me., *Evening Express:*

> Telephone operators are proverbially faithful to their jobs, but the devotion and courage of these Rumford girls was one example of the heroism and devotion that most men and women show in times like this . . . there is probably not an exchange in Maine, or in the country, for that matter, the workers of which would not have done the same thing.

Said a special writer in the Erie, Pa., *Dispatch Herald:*

> Probably one of the largest groups of unsung heroes in the time of disaster are the telephone employees. They are the last ones to leave their posts and far too often they don't leave until it is too late for them to escape the fury of the flood or the crumpling of the walls in an earthquake or tornado. . . . It is the law of all communication companies to give the best service at all times as long as it is humanly possible. This slogan will be found on the wall of every branch of the great Bell System.

From the *Record* of Plymouth, N. H., comes this summary:

> Again and again during the past week we heard praises sung of the local telephone operators and their splendid work. . . What a wonder it was that we did not lose the telephone. All through the two floods we were in touch with the outside world.

Under the caption "Heroines of the Flood," the *Daily Intelligencer,* of Doylestown, Pa., published the following editorial:

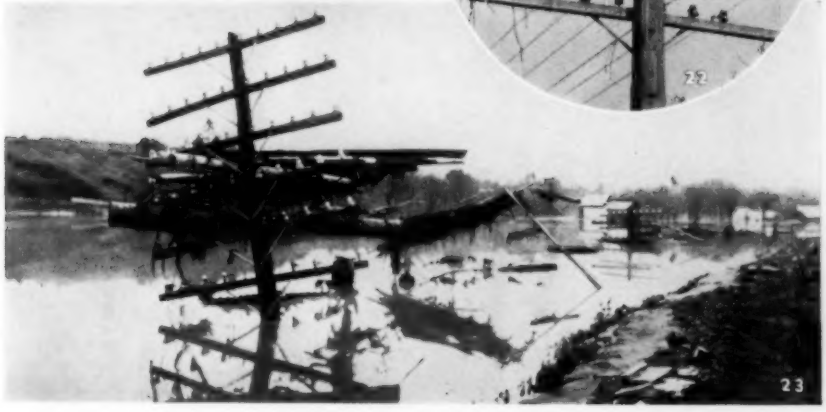
> Among the heroes of the flood whose praises have been sung, very little has been known, perhaps, of the extent of the heroic service given by telephone operators and maintenance crews that stuck to the last in their effort to give service in an emergency when it was most needed and most difficult and dangerous to maintain.
>
> The " log " of the bulletins received from various points by the Bell Telephone Company is an enlightening testimonial of the desperate efforts made by the employes to keep the service going to the last minute possible—even though the lines were being operated on the emergency batteries or " the water was within four feet of the operating board," and operators were working in the dark and chilling cold.
>
> " We are going to stick as long as there is a telephone in service " is one bulletin quoted from Punxsutawney at 4:25 a.m., the zero hour so far as courage is concerned for most persons.
>
> It was through these heroic operators, mostly girls, that the world outside was kept acquainted with the terror and destruction and need that existed—hastening the arrival of the rescue crews.
>
> But it was all in the line of work for these courageous employes with their high sense of duty.

The *Spectator* of Somerset, Massachusetts, published the following tribute to the telephone organization:

> Ordinarily we take the modern telephone's marvellous convenience without a thought. But for the way in which this service struggled through the flood's devastation we owe an expression of gratitude. This gratitude must take into account the individuals, official and employee, who worked so hard, answered

Typical problems which confronted telephone plant crews:

20. *Concord, N. H.* (*Boston Traveler Photo*). 21. *Toronto, O.* 22. *This International News Photo shows a line in Maryland.* 23. *At Westminster, near Bellows Falls, Vt.*



After the water had receded:

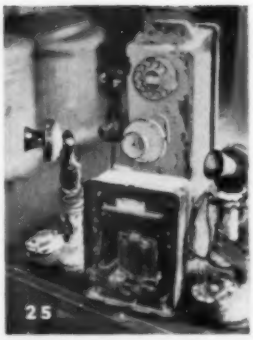
24. *A PBX at Cumberland, Md.*

25. *Mud-coated telephones at Williamsport, Pa.*

26. *An installer trying to find working pairs at Pittsburgh.*

27. *Ruined cable duct on bridge at Montgomery, Pa.*

28. *Inside the Western Electric warehouse at Pittsburgh.*



> so patiently, explained so clearly, surmounted so many unguessed obstacles, to put our message through. They did a splendid job; the swiftness of their repairs since the flood has been equally notable. In order that they might serve us they did something more than we pay them for. They deserve our unstinted thanks.

And in this outpouring of generous sentiment there appears, further, a recognition that the demands upon telephone service that are generated by emergencies are different from those of day-to-day routine only in degree, not in kind. It is indeed true that flood, fire and tornado merely hold, as it were, a magnifying glass over a nation's daily need for dependable telephone plant and devoted telephone personnel. Telephone equipment functions dependably under abnormal conditions because it has been brought nearer and nearer to perfection through long years of development to meet the needs of normal conditions. Telephone men and women rise to meet extraordinary demands because they have learned to meet ordinary demands effectively.

The testimony of flood sufferers is yet being voiced and written. It must be pleasant reading to the Bell System personnel concerned, for it is good to be endorsed by the testimony of eye-witnesses—by those who know. But there were those who were not eye-witnesses, yet who knew just as accurately as though they too had been on the spot. They were other telephone people, who had met the challenge of hurricanes in Florida and earthquakes in California, of floods in the Mississippi Valley and cruel sleet storms in the Northwest. They knew what would be done before it was done because it was what they would do themselves. Ask them their verdict and it would be expressed in a single phrase—"A real telephone job."

R. T. Barrett

Further By-Products of Telephone Research

Editor's Note:

This is the second of two articles by members of the staff of the Bell Telephone Laboratories that discuss the effect of telephone research on social and business activities outside of the communications field. In the January issue of the QUARTERLY, *Mr. Steinberg told of the aids to those of impaired hearing that resulted from this research. In the following article Mr. Mills writes of the new amusement arts that have similarly resulted.*

ANY basic invention—and it is particularly true of the telephone—opens the way for thousands of succeeding inventions which perfect the originally crude mechanism, extend and elaborate the principles of its operation and develop application of these principles to uses far removed from that of the original invention. An expanding field of application is inevitable; as the invention is perfected, new arts arise and older arts profit by the new techniques and instrumentalities. With each improvement in the device of the original invention, further possibilities for its application become evident. As knowledge of the device and of its physical principles becomes more widely disseminated, and as these principles become more generalized and less specific, applications increase in variety and importance.

The moment, for example, that Dr. Bell invented the telephone—the electrical system which permits oral communication—it became inevitable that the system should be extended to permit more than a single person to listen to a distant speaker. This could be accomplished by providing at one end of the line either a number of receivers in multiple, so that each reproduced for its listener the speech which the transmitter picked up at the other end, or a single more powerful re-

ceiver which could radiate the sound to a group of persons assembled before it. In either case the physical principles of Dr. Bell's invention permitted what today we would call "public address."*

The possible use of the telephone in a public-address system was early recognized, as was also the fact that it might transmit music for the esthetics of its sound instead of speech for its content of information. Commercial application of these ideas lagged far behind their recognition for two main reasons. In the first place a much larger amount of energy is needed at the receiving end of a telephone circuit if a loudspeaker type of receiver is used which must spread the energy over a considerable space. This makes desirable some amplifying means for increasing the energy available in the loudspeaker; but there was no basis for amplifiers for the public address until the telephone repeater was developed.

The second reason that public-address systems followed by as many years as they did their underlying basic invention has to do with the acoustic quality of speech. Each syllabic sound of speech is composed, in effect, of a number of pure tones; and its speech significance, its individuality to correspond with the speaker and its emotional content are due to these separate tones and to the relation of their intensities. Of these tones the pitch range which the ear can appreciate extends from about an octave below middle C to about five octaves above. Such a wide pitch range, however, is not necessary for the ordinary purposes of telephony where it is sufficient if the reproduced speech is easily intelligible and is also sufficiently natural so that voices can be easily recognized.

Where music and high quality speech (i.e., program) transmission over loudspeaker systems is involved, very exacting

* The use of the term "public address" in this article reflects historical usage. The term as used today applies to privately owned amplifying systems available for use in auditoriums or at large outdoor gatherings. Such "public address" systems may be connected with program transmission facilities provided by the Bell System but not with the regular local or long distance lines.—*Editor.*

requirements are placed on all parts of the telephone lines which serve the loudspeakers. Whereas in ordinary telephony the requirement is primarily that of good intelligibility of speech sounds, in the use of loudspeakers for musical reproduction naturalness becomes highly important. Today, for example, a range of pitch up to 2800 vibrations per second is very satisfactory in telephony, but is esthetically inadequate in a public address system or in a radio broadcast. Chain broadcasts radiate up to 5000 vibrations, or more, per second although home radio sets may not deliver to their auditors all of that range.

The element which made the public-address system possible, and also provided apparatus and techniques for radio broadcasting, is the telephone repeater. This device was necessary to long-distance telephony. Since speech currents weaken progressively as they travel a telephone line it was soon obvious to those engaged in the art that some device was needed which could receive these currents at the end of one stretch of the line and start out on the succeeding stretch an amplified repetition of them. With such devices installed at successive points along a line there would be practically no limit to the distance over which a telephonic message could proceed. Further, of course, since lines in which the currents weaken least per mile of travel are in general the most expensive, the use of such telephone repeaters would permit the use of lower grade and more economical lines. The long-distance telephone plant of today owes its geographical extent and much of its economy to the successful development and operation of the vacuum-tube telephone repeater.

Without this repeater, or, more strictly, without its amplifying element and auxiliary equipment, public-address systems would have been very limited in range. The repeater was designed to receive speech currents from a line and to supply similar currents of greater energy to the next section of line. Instead of supplying the amplified currents to another

stretch of line, it could serve at the terminal to supply amplified speech currents to a powerful loudspeaker. The current which is to be amplified is a complex one, containing component currents for each of the tones in the speech it bears. In the amplified current there must be similar components but all proportionately strengthened so that the relation of intensities of the component currents is not altered.

The first practical and large-scale utilization of telephonic apparatus and techniques for public address occurred early in 1912 in Chicago, where Yale alumni at a dinner were addressed by their President Hadley from his home in New Haven. They listened through individual head receivers. The amplified current to supply so many receivers came from two telephone repeaters. These were of the so-called mechanical type and consisted in substance of a receiver element and a telephone transmitter element so arranged that speech currents in the receiver operated the transmitter to initiate similar but amplified currents. This device, which was soon to be succeeded by the vacuum-tube repeater, had already performed with some success on long-distance lines.

Public address through multiple receivers reached its peak in number of listeners during the year or so following the opening on January 25, 1915, of the New York-San Francisco telephone circuit. In that pronounced extension of the distance range of telephony—New York-Denver had been the previous limit—the telephone repeater was a vacuum-tube device, developed during the preceding three years in the Bell Laboratories. Demonstrations of transcontinental telephony were made for business and professional groups in a number of places near one or the other of the two ends of this circuit. The largest participation occurred at a meeting of the Telephone Society of New York, where 3250 receivers were provided. Nine hundred members of the corresponding organization in Philadelphia were similarly equipped, 1200 in

Baltimore, and 1000 in San Francisco. These four groups were interconnected, so that all heard the same program, parts of which originated in New York and other parts in San Francisco.

The steps between public address through multiple receivers and public address with more complete reproduction of the speaking voice through loudspeakers, necessarily awaited research studies on all the related problems of the pick-up of sound, its conversion into equivalent electrical currents, its transmission, distortionless amplification, and distortionless reproduction. These problems, of course, have been the subject of continuous study on the part of telephone engineers and scientists ever since the work of Dr. Bell. His invention of the telephone had come, in part, from his recognition of the fact that for telephony it was necessary to produce an undulatory current corresponding to the wave character of the spoken word. He started the investigations which have continued ever since into the character of speech. This is the commodity which the telephone system transmits and reproduces, and it was always well recognized that it was basic to doing a good job in telephony to know with precision the character of the commodity. Telephone lines should obviously be designed to transmit those tones of human speech which are essential to the purposes of telephony; and, similarly, transmitters should be designed to pick up and faithfully convert into components of current all these essential tones, and the receivers faithfully to reproduce them in sound waves.

Transmitters and receivers can be designed which will very accurately and faithfully translate complex sound waves into waves of electricity, and vice versa, but, in general, they are relatively insensitive because they obtain quality at the sacrifice of efficiency. Such precision instruments, however, were not practicable until near the end of the fourth decade of telephony, when the development of the vacuum-tube amplifier

permitted their development. Insensitive but distortionless transmitters and receivers then became practicable because the tube could be used to amplify the feeble current from a high-quality transmitter or to supply amplified current to a high-quality but somewhat unresponsive receiver.

This possibility, which the vacuum tube introduced, was immediately capitalized in Bell System researches. Because it is fundamental to the telephone business to know all that can be found out as to what are the component sounds of speech and as to what is the hearing ability of the ear for such sounds, the Bell System has always been concerned with speech and hearing. The development of the vacuum tube gave power to those researches. Coincident with its development, a large-scale program of intensive research was initiated. In order to investigate the operation of the ear, special telephone receivers were designed which would deliver to it without distortion tones of a wide range of pitch and of a wide range of loudness. For these experiments, the vacuum tube was made to operate as a generator producing alternating currents of any desired frequency and hence corresponding to tones of any desired pitch. Auditory ability was thus mapped out for the entire range of pitch and of loudness of which the ear is capable.

In the analysis of speech, the research investigators set themselves the task of picking up telephonically all the component sounds of speech and of converting them faithfully into corresponding components of current. They planned, in other words, to construct devices so perfect that even the keenest ear could not find a flaw in their rendition, and then, by controlling the current through electrical filters or other circuit elements, to introduce measured amounts of imperfection until an observer could just detect a fault. In that way they expected to reach a quantitative understanding of the importance of the various component sounds of speech. These investigations necessarily carried somewhat into the field of music, where

they produced important information. The clear knowledge of the nature of sound that was derived from these studies, which have been continued ever since, has been an important factor in the improvement in the quality of telephone conversations in recent years; and it has been the basis of the enormous advances which have been made in public-address systems and in the related fields of phonographic reproduction of music, of sound-motion pictures, and of radio broadcasting.

Instruments of remarkable precision were required in the conduct of these investigations, because if the scientists were to measure the smallest detectable variations in sound, they had obviously to use equipment which was capable of a degree of exactness beyond those small quantities. The instruments which they developed were necessary to their investigations, but they quickly found other important uses. A telephone transmitter—technically known as the "condenser" type—which was developed in the early stages of those studies served in the application of telephonic techniques to the production of phonograph records. And that same microphone became the "mike" in radio broadcasting and in sound-motion pictures. Talking motion-pictures owe their success and much of their apparatus to those investigations.

While these investigations were going on, there were simultaneously carried out in the development and design groups of Bell Laboratories other developments which have had their effect upon these fields. For public-address systems there were developments of high-power receivers which could reproduce for a large audience. As early, for example, as 1913, Western Electric equipment had been used for a successful loudspeaker demonstration between Oklahoma City and Tulsa. The Governor of Oklahoma, speaking over 122 miles of telephone line, addressed an audience in Tulsa.

By 1916 the development had reached a point where something of the future possibilities could be envisaged. At the

Newark (New Jersey) Velodrome there was set up a public-address system, supplying eighteen loudspeakers, which were capable of addressing twelve thousand persons. These loudspeakers were supplied with amplified currents from vacuum tubes. A much improved and larger installation was that along "Victory Way" in New York City in 1919. One hundred and thirteen loudspeakers, strung along Park Avenue from 46th to 49th Streets, were actuated by a single telephone transmitter. To this public-address system connections were also made from long-distance telephone circuits and from an electric phonograph for the reproduction of music from records.

A year later, in Chicago and San Francisco respectively, the national conventions of the Republicans and of the Democrats were held with the aid of public-address systems. In May, 1921, an installation was made by the Western Electric for the United States Chamber of Commerce Convention which was held on the million dollar pier in Atlantic City. There were connections as desired to long-distance telephone lines and to phonographs as well as to a newly developed microphone of the double-button carbon type. The condenser-type microphone had had its initial commercial appearance some time before.

Of all the public-address installations during those years perhaps the most impressive, and certainly the most elaborate, was that set up on Armistice Day, 1921, in connection with the broadcasting of ceremonies attendant upon the burial in Arlington Cemetery of The Unknown Soldier. Through public-address systems of Western Electric manufacture, on the designs of Bell Laboratories, and through the long-distance telephone, large crowds participated in those exercises, a hundred thousand at Arlington, thirty thousand in Madison Square Garden and in an over-flow meeting, and twenty thousand more in San Francisco.

This patriotic demonstration of 1921 was equally a demonstration that there had been introduced into the affairs of

men a new technological factor. No longer was the audience of an orator or musician definitely limited by the range of his own voice or that of his instrument. Wherever speech-bearing currents could be delivered, an installation of amplifiers and loudspeakers would reproduce for any size of audience. It made no difference whether these speech-bearing or music-bearing currents arrived at the amplifier over wires or by radio, or, as is the usual case today, by wire from studio to radio station and by radio for their dissemination throughout the immediately surrounding area. The telephone transmitter, improved by researches, had become the microphone for public address and broadcasting. The telephone receiver, similarly metamorphosed, had become the loudspeaker. And the vacuum tube, which had already extended the distance range of telephony and had demonstrated its function in radio telephony,* had become the amplifying element in the new one-way system of electrical communication. The tube itself, to perform its functions of radio detector and amplifier for a loud-speaking receiver, was destined to become the household companion of millions. It was even to surpass in its ubiquity the telephone transmitter itself. In any population, the portion of those who have messages to originate is less than of those who only receive.

The success of public address and broadcasting has been in large part the result of the research development of transmitters and receivers and of their intervening circuits whether these are geographically long as in wire telephony or short as in a radio receiving set. Enough of the component tones of speech and of music could be picked up and reproduced so that the ear of a listener could be pleased as well as informed. The factors underlying quality of reproduction in sound were gen-

* During 1915, Bell Telephone engineers, by transmission from Arlington, Va., to Paris, to Honolulu and to other points, had demonstrated the technical practicability of long-distance radio telephony and laid the foundation for radio broadcasting as well as for the transoceanic and ship-to-shore two-way radio telephony of today.

erally comprehended and further improvements were inevitable. Improvement, in fact, continued and reached its ultimate in April, 1933, in the telephonic transmission from Philadelphia and reproduction in Washington of a concert of the Philadelphia Orchestra. Every component tone of its rendition in Philadelphia, which a human ear in that auditorium could have perceived or appreciated, was reproduced in Washington for the ears of several thousand listeners. The high-quality, high-efficiency loudspeakers, and particularly the introduction of multi-cellular horns, set a new standard of performance. This new standard has been the basis for continued improvements in sound reproducing systems.

The development of a one-way telephone system for reaching immediately and simultaneously a large audience opened the way to other advances. Independent of any need for extending the distance over which a vocal message can be delivered—the social need which the invention of the telephone satisfied—there has always been some need for holding a sound for later delivery. This requirement the phonograph, or talking machine, undertook to satisfy. Through Edison and his successors, mechanical systems were developed for recording in wavy lines, on a disc or cylinder, the vibrations of a diaphragm exposed to sound waves, and for reproducing these vibrations from their records. Like the early telephone, the early machines for this purpose handled only a limited portion of the component tones of speech and reproduced them with the defects of distortion. Unlike the telephone, because the system was mechanical instead of electro-mechanical, the possible improvement in quality of reproduced sound was limited. It had reached its peak by about 1920; and shortly afterwards the phonograph industry was seriously threatened by the competition of radio broadcasting.

What the phonograph undertook to do was to record sound for subsequent reproduction. Into the transmission of sound,

between source and auditor, the phonograph inventor proposed to introduce an indefinite but controllable amount of delay. With its invention, speaking and listening lost their usual temporal relationship. Without its use, words passed through the air as waves of sound, demanding the attention of listeners at the moment of their arrival at their ears or else passing on to be lost forever to the inattentive. Through its use, the sound waves were effectively delayed, awaiting the interest and attention of listeners and resuming travel when that attention had been indicated by starting the phonograph. The sounds could be repeated over and over again merely by restarting the machine, and they were reproducible for anyone who possessed copies of the records and a machine. Just as a printed book carries the written words of its author impersonally to a variety of readers and at many different times, so the phonograph carries the spoken word.

The record was cut by a graver which was driven by a diaphragm which in turn was vibrated by the sound waves that were to be recorded. This mechanical vibrating system was selectively sensitive to pitch, recording well some component tones and making negligible record of others. In addition, it failed to respond to the fainter tones of music or speech. The result was distortion and impairment of the sound and "canned" music or speech, a thing unnatural—to which, however, phonograph users grew more or less accustomed and tolerant.

Phonographs from time to time have been of interest to telephone engineers. As far back as 1910 they were considered as sources of speech for practical tests of telephone transmitters. The phonographs of that day introduced too much distortion into their reproduction of speech, and the project was abandoned except for one of the cruder tests. Today, however, improved types of phonographs are used for many purposes in testing and in telephonic research work.

Another project involving recorded speech was that of supplying telephonic currents corresponding to the spoken sound of numbers and letters so that dialing from a dial office might give rise to spoken words for the guidance of an operator in a manual office. Today that is accomplished by the "call announcer," a device in which currents from film records of speech are supplied to a circuit in accordance with dialed impulses. The first attempt along this direction had a trial in 1916, but the quality of the reproduced speech was too unsatisfactory.

While these attempts to utilize existing mechanisms were going on, the researches on electromagnetic devices, receivers, and transmitters were making rapid progress. As soon as these researches had produced high-quality transmitters and vacuum-tube amplifiers to associate with them, a revolutionary change in the phonograph art became practicable. A microphone could be set to pick up the sound, converting into waves of electricity in wires what a one-eared listener would have heard in its location. The current from the microphone could then be amplified and used electromagnetically to drive the graver. For reproduction, there was used another transmitter which was driven by a needle as it followed the wavy lines of the record. With this device, there were associated a vacuum-tube amplifier and a high-quality loudspeaker. By such electrical arrangements there were avoided the serious limitations which had previously been inherent in the recording and reproducing mechanisms of the phonograph.

The first public showing of this application of telephonic techniques to the phonograph art, and of the progress which had been made in producing electrically-cut records, was made in a lecture during October, 1922, by E. B. Craft, of the Western Electric Company. The lecture hall in New Haven, Conn., was equipped for the purpose with a high-quality amplifier and loudspeaker. This equipment reproduced speech from electrically-cut disc phonograph records. The records con-

tained a spoken discourse intended to accompany a showing of a silent motion picture called "The Audion."

The phonograph was played and its speech reproduced while the picture was being projected. Synchronism sufficient for the purpose was maintained by hand control. The result was a sound motion-picture—not the first, for Edison had done the same thing years before, but the first in which there was high-fidelity reproduction of the sound. Enthusiastic reception of this demonstration indicated some of the future possibilities for sound motion-pictures and encouraged development work along that line.

By the middle of 1924, the Bell Laboratories' development of equipment for electrically cutting phonograph records and for reproducing from them had reached a point where it was obvious that electrically-cut records were suitable for commercial use. The resulting process of recording was licensed early in 1925 to the Columbia Phonograph Company and to the Victor Talking Machine Company, both in this country, and to their associated companies in England. At that time there was some feeling by those concerned with phonograph sales that the public would be unwilling to buy electric reproducing equipment. A purely mechanical, or acoustic, phonograph was then developed and licensed to the Victor Talking Machine Company. This device, which was called the "orthophonic" phonograph, represented the result of the application to the problems of mechanical vibration of the electrical techniques which had been developed during the study of transmitters, receivers, and telephone lines.

Electrically-cut phonograph records had several advantages over the older style of mechanically-cut records. These advantages derived from the application of telephonic techniques, and from the utilization of the latest developments in telephone equipment. When sound is picked up by a mechanical system, as for example a diaphragm which drives a graver, the power

output of the system in cutting wax grooves cannot be greater than the power input of the sound waves. The diaphragm serves to transmit to the graver the air pressure of the sound wave, but not all the power of the wave is delivered because some is lost in overcoming the frictional resistance of the diaphragm.

When, on the other hand, sound is picked up by a carbon-button telephone transmitter, there is an actual amplification of power. The diaphragm in its vibration varies the area of contact of the carbon grains within the button and so varies the electrical resistance of that button. Current flows through the button from a battery, and the amount of current varies with the vibration of the diaphragm. The output of the transmitter in the form of electrical power is not limited to the power input of the sound waves. The mass of carbon grains in the button, which shrinks and expands alternately during the vibration, acts as a valve to control the power output of the battery. What a telephone transmitter accomplishes, therefore, is not merely the translation of air vibrations into electrical, but the production of more powerful electrical, vibrations corresponding to those in air.

Before the application of telephonic methods to the phonograph art, when the wax record was cut by the power of the sound waves, faint tones were lost in recording because they could not drive the graver. A horn was used to direct the sound to the diaphragm, and the artists had to be grouped closely in front of the horn's opening so that their speech and music could exert the greatest possible force on the recording mechanism. An orchestra while recording was arranged in an awkward and unusual manner, and even the instruments were altered. The violins had horn or pipe attachments so as to give greater amount of sound but, of course, not the usual tone quality of a violin. Using a telephone transmitter, all this became unnecessary; the orchestra took its usual seating and

played its regular instruments, while a microphone in front of it picked up the music.

Picking up through a microphone and amplification of its current by vacuum tubes assured greater power for driving the graver. Improvements in transmitters and in loudspeakers, and telephonic developments of an electromagnetic mechanism for driving the graver, completed the revolution of the phonograph art.

While this phonograph development was going on in the Bell Laboratories, there was also progressing a related development. In one of the groups engaged in acoustic investigations, there was developed a photographic method of recording. Speech-bearing currents were caused to operate electrically a shutter or light valve. This controlled the amount of light falling on a moving film and so recorded on the film in variations of photographic density the variations in the current. For reproduction, the film was run between a lamp and a photoelectric cell. The cell originated a current proportional to the amount of light which fell upon it and hence, in turn, proportional to the current which was responsible for the variations in light and shade of the film.

This is the "variable density" method of recording sound on film, which has found world-wide use in Western Electric systems for sound motion-pictures. Some years before it became effective in the motion-picture world, one of its essential elements, the light-valve, and its companion, the photoelectric cell, had been adapted to the telephonic problem of the electrical transmission of pictures. These elements were used in the telephoto system which was put into commercial service in 1925, and are used in the present-day system.

The idea of sound motion-pictures was old, but it did not reach fruition until the telephonic developments in sound recording prepared the way. For sound motion-pictures to be successful, there are three requirements: first, that the picture

itself shall satisfactorily reproduce the scene; second, that the accompanying sound shall in quality of reproduction have sufficient verisimilitude and naturalness; and, third, that the reproduced sound shall be synchronized with the picture. Advances in photography met the first requirement, but it was because of inability to meet the second that early attempts were abortive. The third requirement could not become controlling until the second had been met. It was, however, relatively easy to meet and did not appreciably delay the success of sound pictures.

By 1924 there had been developed telephonic equipment and methods through the use of which there could be met the second requirement for sound pictures. Speech and music could be picked up, recorded, and reproduced for a large audience and with the necessary high quality and faithfulness. For recording, there were available both the method of electrically-cutting disc phonograph records and that of photographically recording the sound as a track on the picture film. The phonograph method was adapted by developing the proper equipment for synchronization. It was then licensed to Warner Brothers, and in 1926 had its premier performance under the trade name of "Vitaphone."

By the summer of 1928, most of the large producers of motion pictures in the United States had been licensed to use Western Electric systems. Of the two available methods, they preferred the photographic. In their studio work, however, they found great convenience in recording simultaneously by both methods, because the wax record could be played back immediately so that "retakes" could be made before the actors were dismissed from the set. For theatre use it was a convenience, on the other hand, to have both sound and scene on the same film. One advantage was the ease of patching when film breaks occurred and some frames of pictures and inches of sound track were lost in the operation of patching. For

theatre use, film recording became preferable and was soon adopted by Warner Brothers also.

The equipment which the Laboratories had originally designed and the Western Electric had manufactured was no crude model: it was a full-fledged system which permitted the production and projection of widely popular sound pictures. The original design, by comparison with the automobile, would stand alongside those models which just preceded stream lining rather than with the horseless carriages of the early years. Science and engineering, however, are dynamic and vital; nothing which they create can satisfy indefinitely; progress is inevitable. No sooner, therefore, had the Laboratories proved its design through its commercial acceptance than new features of design took form in the inventive minds of those engineers most concerned; new applications of ideas just derived from fundamental telephonic researches pressed for apparatus embodiment in improved sound-picture equipment. The necessary development work was therefore undertaken and from it have come many important advances, chief of which in popular appeal are the "noiseless recording" that was introduced to the theatres some years ago, and the "wide range recording" which increased the exactness of sound reproduction.

Although much progress has been made since 1928, when the sound picture became universal, the fundamentals upon which the art stands are the telephonic researches of the preceding half century, and particularly of the years 1912 to 1924. It was those years which produced also the public-address system, improved methods of recording, and basic techniques and equipment for radio broadcasting.

JOHN MILLS

Behind the Scenes in a Central Office

TO the every-day telephone user, the telephone central office is a vague entity in the background of the service where, in some mysterious fashion, connections are established, in response to his orders, with whomsoever it may be his desire to reach.

This central office is the heart of the telephone network, and upon its proper functioning depends to a vital degree the quality of the telephone service and the subscriber's impression of it. The central office is the doorway to the telephone world. Every subscriber's line centers there, and through it each subscriber is given access to each of the hundreds or thousands of other subscribers in his own community and to those in neighboring communities, anywhere in the state or nation and, indeed, to nearly every telephone throughout the nations of the world. There is a local central office for almost every community: over six thousand of them in the Bell System. Through interconnecting lines and trunks and through the medium of long distance switchboards, they are linked into one common system to provide a unified telephone service for the country as a whole.

To many, the central office is a switchboard where operators sit before a bank of blinking lights, reaching for them with plugs on the ends of long cords and saying "Number, please,—Thank you," "Number, please,—Thank you," all day long. Close examination of that switchboard will reveal that it is made up of many small operating parts, such as keys, lamps, jacks, plugs, and cords which, all told, quickly count up to hundreds even on a small switchboard in a country town. And in the inside of the switchboard and in the apparatus or terminal rooms are other hundreds of small operating parts which are

necessary to make the lamps light, to ring the bells, and to perform the countless other mechanical and electrical operations essential to the rendering of telephone service. In the bigger towns and cities, the switchboards are much larger, including cities where the dial system is used to complete local calls, and the number of individual operating mechanisms required to perform the central office functions mount up to hundreds of thousands in each office. In dial offices the equipment is most complex, a much greater variety as well as quantity of mechanisms being needed to perform the intricate switching operations involved in setting up calls mechanically.

Large as may be the quantity and variety of electrical and mechanical units of which the central office is composed, they must all work together with the reliability and precision of a single well-oiled machine. Even the most simple form of telephone connection calls into play the joint operation of at least a dozen different mechanical elements of the central office equipment, either at the switchboard or in the associated equipment. The more complex dial connection may employ several hundreds of these unit mechanisms on a single call. The great majority of the equipment units are used over and over again by different calls, sometimes for only a few operations a day, commonly for several hundred operations a day, and in some cases tens of thousands of times a day.

To meet the demands of this exacting service, the equipment is, of necessity, ruggedly designed and built to perform its functions with a minimum of attention. It is to be expected, however, that in time there will be a certain amount of deterioration due to wear, fatigue, dirt, corrosion, etc., which must be compensated for by adjustment, repair, and cleaning operations to ensure continued good telephone service to every subscriber. This, in general, is the function of the central office maintenance forces, comprising many thousands of plant men in the Bell System, and the methods which they employ and the tools which they use are largely the product of activities of

hundreds of other men distributed through the several supervisory and engineering staff groups in the telephone organization.

Maintenance activities, in general, may be roughly grouped in two categories, the one preventive and the other corrective. In telephone practice, prevention of operating irregularities is the paramount objective, and preventive maintenance, therefore, occupies the major position in the maintenance program; but corrective maintenance is also a necessary part of the maintenance man's duties. In addition, the maintenance forces have certain other operating functions, such as connecting, disconnecting, and rearranging the wiring whereby subscribers' lines are connected to the central office equipment, and the routine operation of the power plant, which is part of the central office equipment. For the sake of simplicity, we shall confine our attention to the functions which are more directly concerned with keeping the equipment in good working order.

Preventive Maintenance

One of the principal processes of preventive maintenance is so-called routine tests or inspections, and these play a large part in the work assignments of the central office maintenance man. The "routines" are regularly scheduled physical examinations or electrical tests of particular parts of the equipment, designed to disclose faulty conditions that may require correction. A routine inspection, for example, may involve a measurement, with suitable gauges, of the physical condition of switchboard plugs, intended to show what plugs, if any, may have become worn or damaged to the extent that they are on the verge of causing "cut-outs." Such an inspection would be scheduled often enough to eliminate practically all the potentially defective plugs before they cause service reaction. Similarly, inspections are made on other apparatus to determine the condition of wear or adjustment and the general state of

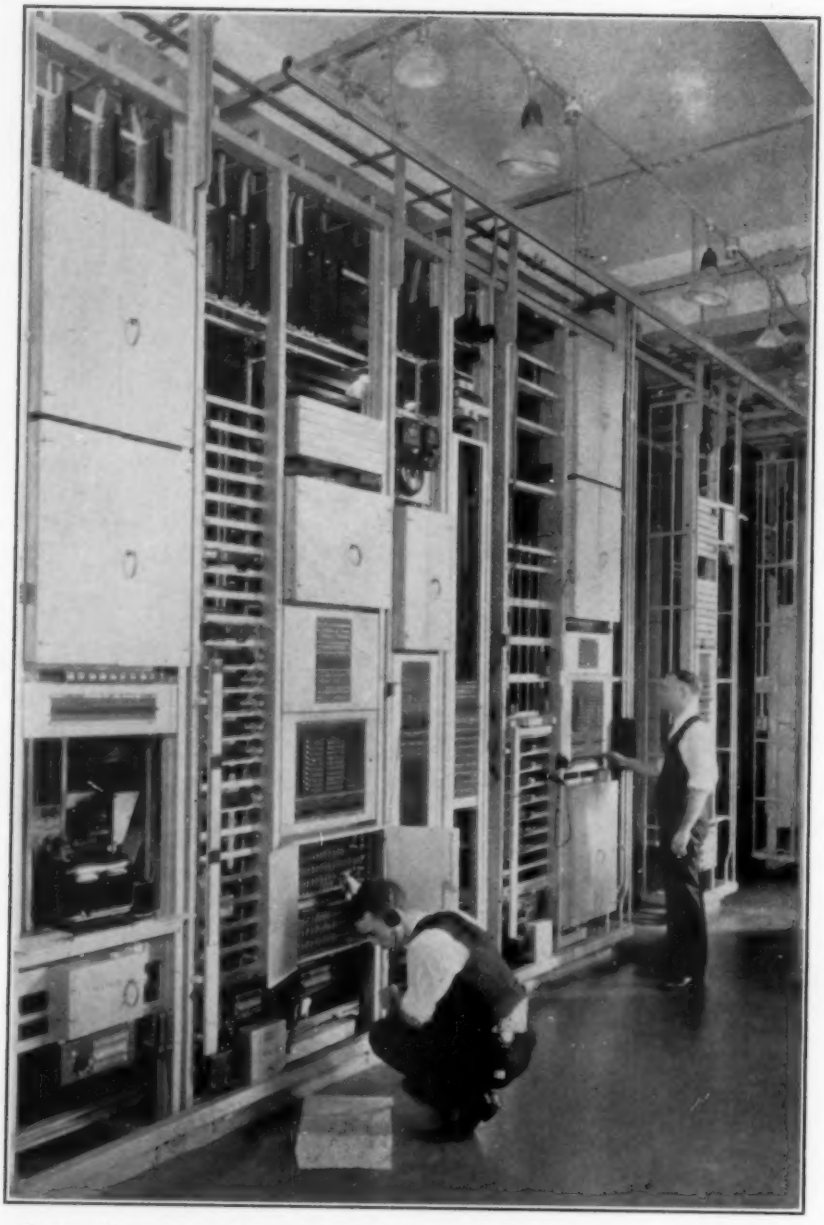
repair or cleanliness. Special tools or gauges are employed to facilitate these operations.

Because routine inspections might at times have a tendency to disturb working equipment through unnecessary handling of parts which are in good working order, they have, in recent years, been restricted to those few items of equipment where the inspection method was particularly appropriate, and greater emphasis has been placed on routine tests. These are, for the most part, electrical tests of the operating functions of the equipment, performed more or less in a manner corresponding to the way the equipment is used in service, and are, therefore, not disturbing to the equipment.

A typical routine test, for example, would be an operation test of a switchboard cord circuit: i.e., of the combination of cords, plugs, keys, lamps, relays, etc., which functions as a unit to provide the means whereby an operator may connect one line with another at the switchboard. The test would consist of connecting the cord circuit to certain testing equipment and of manipulating various keys in such a manner as to bring into play the operating features of the cord circuit. Thus the cord circuit would be tested for the ability to give the proper lamp signal when connected to the line of a calling party, together with the proper signals when that party disconnects or wishes to recall the operator; it would be tested for the ability to ring on a called line and to receive the proper signal when the called party answers or disconnects; and it would be tested for other operating features such as the collection or return of coins at a coin telephone.

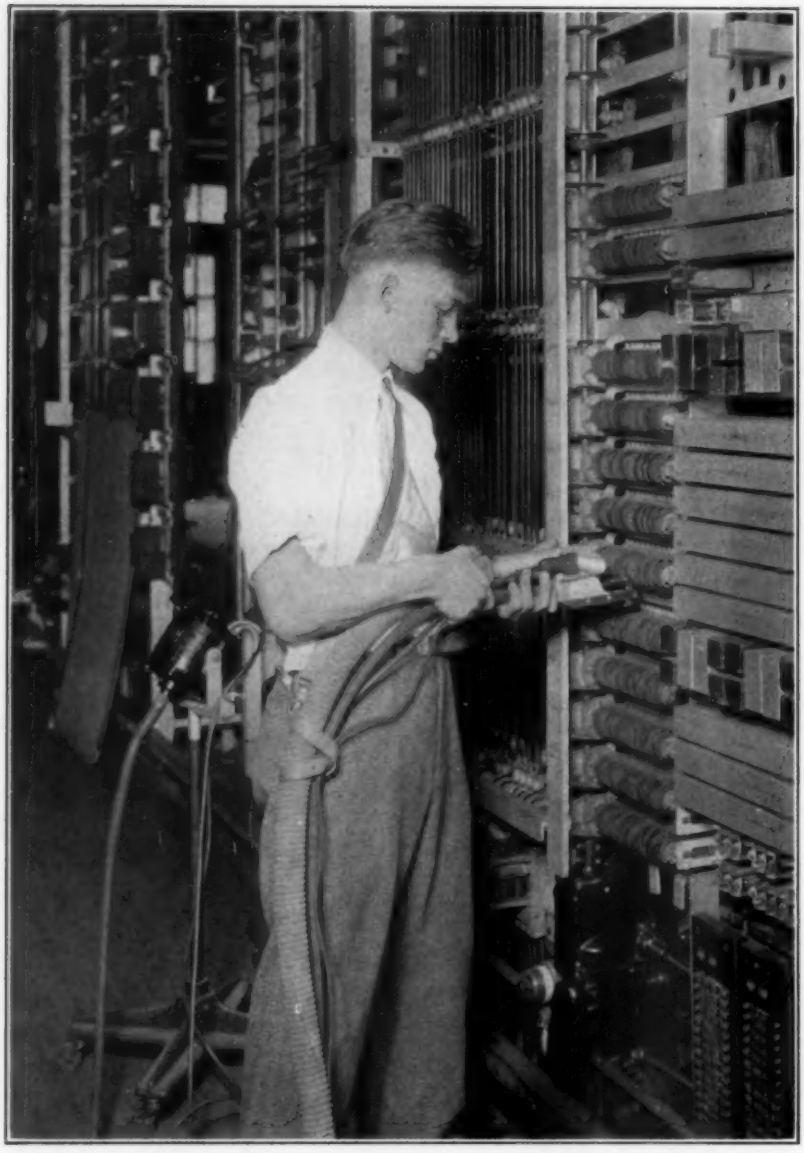
In making these tests, the testing equipment is arranged to simulate as far as possible the most rigid operating requirements for each of the features, so that irregular conditions will be indicated before they affect service. Such routine tests provide a means of periodically checking the equipment for operating capability and show where potential trouble may exist. Each fault is corrected as found; but if the tendency is for

ROUTINE TESTING IN A STEP-BY-STEP DIAL OFFICE.



TRACING TROUBLE ON A CIRCUIT, AND OPERATING A TEST FRAME, IN A PANEL-TYPE DIAL OFFICE.

Adjusting Relays in a Step-by-step Dial Office.



COMBINED MECHANICAL AND VACUUM CLEANING OF SEQUENCE SWITCHES IN A PANEL-TYPE DIAL OFFICE.

more defects of a particular kind to appear than past experience has shown to be normal, extra measures, such as special inspections or reconditioning operations, are then undertaken, to discover the cause for any such unfavorable trend and apply the proper correction. The routines thus serve either as a direct means of eliminating the faulty conditions or as a measure of equipment conditions by which the need for other maintenance treatment is indicated.

Still one other group of "routines" should be mentioned as having a major place in the maintenance man's trouble preventive program: namely, certain periodically recurring work operations which are concerned with preserving desirable physical conditions in the equipment or its environment. In this category, the chief items are lubrication and cleaning. Lubrication is necessary in many of the mechanisms to prevent wear or corrosion. Manual office equipment does not require lubrication to any great extent, but in dial offices the various switching mechanisms have many small bearings or impact points which must be kept lubricated. Since these points of lubrication may number in the tens of thousands in a single office, it can be seen that lubrication on the average of even once a year is a sizable work assignment.

The routine cleaning operations collectively constitute an even greater task and, of course, apply to all types of offices. The cleaning work ranges from simple dusting operations with cloth or vacuum cleaner on the exposed surfaces of the equipment to more specialized abrasive polishing and treating of contact surfaces, such as, for example, the periodic polishing of switchboard plugs to remove tarnish. The cleaning efforts are important from the preventive maintenance viewpoint because the essential function of all the relays and other switching devices comprising the equipment of the telephone office is the opening and closing of hundreds of thousands of small contacts that complete the electrical circuits hundreds or thousands of times a day. Modern telephone design has produced contacts

that are virtually perfect in performance, when the millions upon millions of operations expected of them in their useful service life are taken into account. But considering the large number of contact closures required for even a single call, the maintenance objective is to prevent even the random contact failures which may occur as infrequently as once in several hundred thousand contact closures. All the cleaning operations contribute to this objective by preventing the accumulation of dirt or products of corrosion that might interfere with the proper operation of the equipment.

The various routine tests, inspections, and other work operations are administered according to a definite schedule which has been worked out by experience to provide a systematic coverage of most of the operating equipment within some definite time interval. This interval varies for different parts of the equipment according to their nature, the rate of use to which they are subjected in service, the past experience as to their susceptibility to trouble, etc. Thus certain routines may be performed only once a year, while others may be done quarterly, monthly, weekly, or even once a day in some few cases. This program serves to detect the great majority of irregularities that are likely to affect service but, without going to excessively costly extremes, there will still be some irregularities which will show up in operation. This leads us to a consideration of the corrective type of maintenance activity, which originates in the work of trouble tracing as the result of circuit alarms or reports from external sources.

Corrective Maintenance

The circuit alarms are signal arrangements incorporated in the equipment to provide automatic indication of certain kinds of operating irregularities or failures. When a fuse operates, for example, as the result, perhaps, of a short circuit in some part of the wiring, one or more lamps light and a bell is sounded in the terminal room where the equipment is located. The

lamps indicate the kind of failure that has occurred and guide the maintenance man to the part of the equipment which is affected. There are various alarms of this general type, which call attention not only to blown fuses but also to certain irregular conditions, such as the failure of one of the automatic selectors in a dial office to release properly at the end of a call. These alarm arrangements maintain automatic supervision over many of the central office equipment functions. They operate, of course, only when some sort of irregularity has occurred, but because they are virtually instantaneous in their indication, they are an important adjunct to the preventive maintenance program and afford a continuous safeguard to service. They can be utilized by the maintenance forces as a means of disclosing certain kinds of potential trouble conditions, and in that respect function somewhat like routine tests to indicate when certain special preventive or corrective maintenance work may be required.

Such relatively few troubles affecting service as do occur through conditions not disclosed by preventive maintenance, or those occurring between routine tests, are usually brought to the attention of the maintenance forces by operators' or subscribers' reports. An operator, because of her continual use of the circuits, is in a position to detect certain types of irregularities quite promptly during their occurrence, or at least more quickly than they would be disclosed by routine tests. When she does notice such equipment irregularities, she brings them to the attention of the maintenance forces either orally or by means of a "trouble ticket," in accordance with the reporting routine followed in that particular office. The maintenance man investigates these reports by making appropriate tests or inspections of the equipment involved, and locates and corrects whatever faulty conditions may be present. Similarly, the subscribers in their use of the service experience occasional difficulty on a call and make reports to the operators or to the repair bureau, which are relayed to the central office mainte-

nance forces if central office trouble is indicated as a possible cause of the difficulty. The maintenance man is required to analyze such trouble reports to determine what part of the equipment might be responsible for the fault, after which he makes the necessary tests and inspections to localize possible irregular equipment conditions.

Tools and Testing Equipment

For the performance of the numerous and varied operations that are expected of him, the maintenance man is provided with many special types of tools and testing devices, each especially designed for its particular purpose. The use of gauges and test sets in the performance of routine and trouble-clearing tests and inspections has been indicated. In addition, the repair and adjustment work may require other special tools and testing devices.

The tools may be simple devices such as wrenches or screw drivers, sometimes with slightly special shapes to facilitate access to and ready manipulation of adjusting nuts and screws in the performance of some of the more frequent types of adjustment work; or they may be quite elaborate kits of tools such as might be required for commonly recurring repair operations, of which switchboard cord repairs, involving the cutting back of frayed cord ends, "serving" the cords, "tipping" the conductors, and replacing the plugs, might be cited as a typical example. The gauges used in inspection and adjustment work are special measuring devices by which the essential dimensions of the apparatus, as, for example, spring tension, armature travels, contact point clearance, etc., may be checked, to detect either wear or the condition of adjustment. They, too, may be very simple or quite complex. The testing equipment may be small portable devices such as meters or testing circuits assembled in carrying cases, or it may take the form of permanently mounted equipment arranged to be controlled

Cleaning and Adjusting Switchboard Keys.

REPAIRING SWITCHBOARD CORDS.

from a distance or to perform tests automatically, as in the case of some of the testing equipment used in dial offices.

All of these tools, gauges, and testing devices are designed with a view to providing the most convenient, efficient, and accurate arrangements possible in consideration of the highly repetitive nature of most of the work operations in which they must be used. They incorporate the necessary features whereby the mechanical or electrical condition of the equipment may be checked and assured to be proper for the various service conditions in which it may be employed.

Methods and Technical Information

It will be apparent that the knowledge which is required of the central office maintenance man is of a highly specialized character. Even with a broad basic knowledge of his duties, the specific details are so numerous and varied and the developments in the art are so rapid that he must be provided with considerable technical reference and instruction material to equip him fully for the day-by-day conduct of his job. This is provided in the form of blue-print drawings and circuit description pamphlets and more particularly in a series of standard practice instructions called "Bell System Practices."

The drawings give equipment and wiring information and some adjusting information and the "circuit descriptions" tell how the equipment works. The Practices cover the methods of doing the specific maintenance work operations and give various kinds of data that are needed in the course of the work. Thus there will be a section of Practices covering each routine test, for example, telling what testing equipment to use, how to set it up and connect it for the test, how to operate it to make the particular kinds of tests to which the equipment should be subjected, and what the indications of satisfactory or improper operation may be. There will be a section describing each adjustment procedure and the more complicated types of repair operations. The adjustment sections, together with the

adjusting information on the circuit drawings, will give the various dimensional or electrical testing limits by which the apparatus may be checked for operating capability and, usually,

BELL SYSTEM PRACTICES
Central Office Maintenance
Tests and Inspections

SECTION A252.002
Issue 3, 1-18-34
Standard

SELECTOR OPERATION TEST

USING TEST SET SD-90210-01 OR SD-90416-01

350 AND 360 COMMUNITY DIAL OFFICES

1. GENERAL

1.01 This section describes a method of testing the pulsing, cut-in, holding, releasing and switching-through functions of local selectors.

1.02 This section has been reissued to provide for the use of test set SD-90416-01.

1.03 Different levels should be used each time this test is performed, so that eventually every selector will have been tested for cutting in on each level.

1.04 When testing an incoming selector, the trunks should be made busy in the approved manner during the test.

1.05 If a failure is encountered on any selector, it should be held busy in the approved manner until the trouble is cleared.

2. APPARATUS

2.01 Test Set SD-90210-01 (J34704A) or SD-90416-01 (J94704A).

2.02 One P3C Cord equipped at one end with a No. 110 Plug and at the other end with a No. 240-A Plug.

2.03 One P3E Cord equipped with No. 110 Plugs.

3. PREPARATION

3.01 Locate the test set at the selector frame.

3.02 Connect the BAT-G jack of the test set to the 48-volt battery supply jack located on the selector frame using the P3E cord.

3.03 Insert the No. 110 plug of the P3C cord into the T jack of the test set.

3.04 When using test set SD-90210-01 operate the SD key and leave it in the operated position during the tests.

3.05 Insert the No. 240-A plug of the P3C cord into the test jack of the selector to be tested. If the switch is busy the BSY lamp on the test set will light, in which case the plug may either be removed in order to proceed with other tests, or left in the test jack and the test delayed until the BSY lamp is extinguished.

4. METHOD

4.01 Operate the LP key and note that the HSY lamp on the test set lights.

4.02 When testing selectors arranged to absorb the initial digit on all levels or selectors arranged to absorb the initial digit on individual levels as required, an extra digit must be dialed before proceeding with the operation test as outlined in 4.04, on levels arranged in this manner.

4.03 When testing selectors arranged to absorb digits repeatedly on one or more levels, dial the digit for the particular level arranged in this manner several times and note that the switch releases after each series of pulses.

4.04 Dial the designated level and note that the switch steps smoothly to the proper level and rotates to an idle contact. The REV lamp on the test set should not light. In event the REV lamp lights, the indication is that the tip and ring wiring of the selector is reversed.

Note: In offices where vacant level trunks are made busy, the switch should rotate to the 11th rotary position when a vacant level is dialed.

4.05 Release the switch by restoring the LP key. Note that the HSY lamp on the test set is extinguished when the switch releases.

4.06 Operate the LK key and repeat the operations described in 4.04 and 4.05 with the LK key operated instead of the LP key.

5. REPORTS

5.01 The required record of these tests should be entered on the proper form.

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A Section from Bell System Maintenance Practices, Describing a Routine Test.

a closer set of limits to which it should be readjusted so as to ensure some added margin of safety against deterioration of the adjustment with time. The repair sections will give constructional details and information for identifying repair parts in ordering from the supplier, together with detailed instructions on dismantling and assembling the apparatus and methods of effecting repairs where old parts are reused. There will also be sections covering the technical details of most of the commonly recurring work operations such as the methods of tracing circuit alarms, the methods of handling trouble reports, the methods of operating the power equipment, etc., and various descriptive sections of an informative or educational character on matters related to the maintenance function.

These Practices, being issued in sectional form averaging five or six pages each, are readily kept up to date by reissues, so that the maintenance forces may be quickly informed of the development of new or improved methods of doing maintenance work, or of the use of new tools, testing devices, materials, etc., as they become available.

The present day methods of maintenance and the tools, testing devices and other facilities which contribute to their efficiency are the result of many years of experience and development effort. These methods today are the best that human ingenuity has been able to devise, but suggestions from the field maintenance forces growing out of their day-by-day operating experience, and the findings of study and research on the part of the staff groups of the A. T. & T. Company and the Bell Telephone Laboratories, are continually pointing the way to new methods of doing the work and to better facilities for the task. The objective of the telephone maintenance man is improvement, a constant striving toward the goal of perfection that is so characteristic of the great telephone family of which he is such a necessary and vital part.

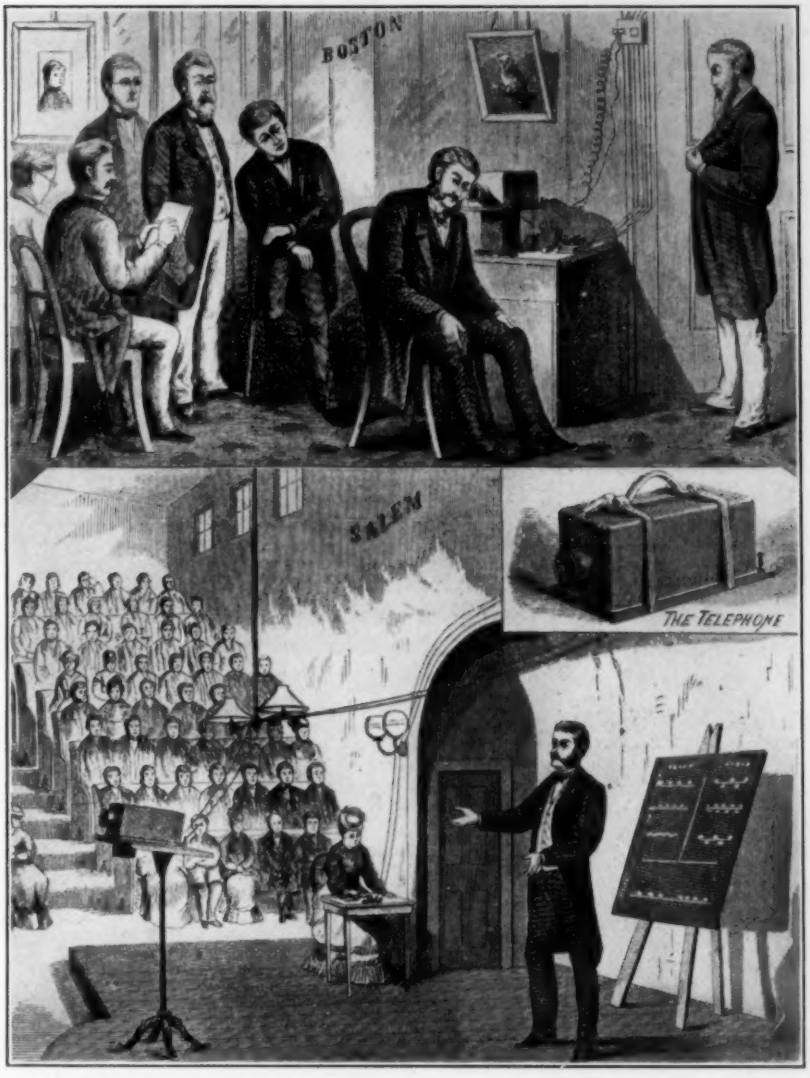
P. C. SCHWANTES, JR.

Some Early Telephone Prophecies

WHEN the telephone was first introduced, it was regarded with apathy or skepticism by the general public, and there were probably very few people, outside of its inventor, Alexander Graham Bell, and his immediate associates, who had any confidence in its future. Even for some years after the inauguration of a commercial telephone business, the full nature of its possibilities was not generally recognized. With this situation in mind, therefore, it is interesting to discover that there were, even in those early days, at least a few people gifted with prophetic vision or vivid imagination, and it is the purpose of this article to bring together, within the space of a few pages, a number of prophecies—serious and otherwise—regarding the future possibilities of the telephone, that appeared in print during the first few years after the invention of that important instrument.

In this list of examples of prophetic vision, first place will be awarded to Alexander Graham Bell's prospectus, written at Kensington, England, on March 25, 1878, for the purpose of promoting the use of the telephone in that country. This document was written at a time when the telephone art and business were as yet undeveloped, when there were no telephone cables and no commercially practical transmitter, and when the first telephone exchange had been in operation less than two months. The following paragraph from this prospectus will be familiar to most readers, since it has been reprinted many times:

> It is conceivable that cables of telephone wires could be laid underground, or suspended overhead, communicating by branch wires with private dwellings, country houses, shops, manufactories, etc., etc., uniting them through the main cable with a central office where the wires could be connected as desired, establishing direct communication between any



THIS WOOD CUT, REPRODUCED FROM THE SCIENTIFIC AMERICAN OF MARCH 31, 1877, SHOWS ALEXANDER GRAHAM BELL LECTURING TO AN AUDIENCE AT SALEM, MASS. THE INVENTOR IS ILLUSTRATING HIS DEMONSTRATION BY MEANS OF A TELEPHONE PLACED BEFORE HIS AUDIENCE AND COMMUNICATING WITH HIS LABORATORY AT BOSTON, FOURTEEN MILES AWAY.

two places in the city. Such a plan as this, though impracticable at the present moment, will, I firmly believe, be the outcome of the introduction of the telephone to the public. Not only so, but I believe, in the future, wires will unite the head offices of the Telephone Company in different cities, and a man in one part of the country may communicate by word of mouth with another in a distant place.

Another striking example of prophetic vision is the certificate of incorporation of the American Telephone and Telegraph Company, filed on March 3, 1885. The following paragraph from this certificate has also been quoted on many occasions:

And it is further declared and certified that the general route of the lines of this association, in addition to those hereinbefore described or designated, will connect one or more points in each and every city, town or place in the State of New York with one or more points in each and every other city, town or place in said state, and in each and every other of the United States, and in Canada and Mexico; and each and every other of said cities, towns and places is to be connected with each and every other city, town or place in said states and countries, and also by cable and other appropriate means with the rest of the known world, as may hereafter become necessary or desirable in conducting the business of this association.

The above words were written at a time when intercommunication by telephone was limited to about 250 miles, 30 years prior to the completion of the first transcontinental line, and over 40 years prior to the inauguration of transoceanic telephone service.

Another prophetic statement is contained in the first annual report of the Mechanical Department of the American Bell Telephone Company, signed by E. T. Gilliland, Superintendent, and dated February 18, 1885:

That this Department will become more useful to the Company as time goes on cannot be doubted. New and unexpected channels of usefulness will appear and the general aim of all our work should be not merely the improvement of the service in special directions but the establishment of uniformity in methods employed by different exchanges looking to the adoption of one universal telephone system.

This is thought to be one of the earliest references, if not the earliest, to the necessity for uniformity in methods throughout the Bell System. At the time when these lines were written, there were twelve employees in the Mechanical Department, including Mr. Gilliland, and less than twenty-five in the entire technical staff of the American Bell Company. There were 135,000 telephones in the Bell System and 137,000 miles of wire.

Reference will next be made to a number of news articles that appeared in the public press at a somewhat earlier period —in fact, very shortly after the invention of the telephone. Readers familiar with the sequence of events preceding the inauguration of a commercial telephone business, in May, 1877, will remember that Bell's telephone was patented in March, 1876, and first brought to the notice of the general public by his paper "Researches in Telephony," read before the American Academy of Arts and Sciences on May 10, 1876, and by its exhibition at the Centennial Exposition in Philadelphia in the following month. Bell spent the next few months in improving his telephone and in trying out its capabilities on existing telegraph lines. He also delivered a series of lectures, in various cities, during the winter and spring of the year 1877, designed to popularize the use of the telephone. These experiments and lectures—the latter being accompanied by demonstrations of the transmission of speech and music between places separated by a moderate distance—were given wide publicity in the newspapers of the United States, and in view of the fact that the only telephonic apparatus or equipment in existence at the time was Bell's crude box telephone, operating without a battery, some of the prophecies contained in the following press notices are quite astonishing:

Springfield Republican, February 15, 1877

Prof. Bell, the accomplished teacher of "Visible Speech," has been experimenting, for a year or two, on a method of making speech audible,

through the telegraph, at a distance of many miles, and has had, of late, much success in this. On Monday night, he placed one of his instruments in Salem, and another in Boston, and was able to transmit words and tones back and forth, and even to send applause by telegraph. The instrument used is termed by him the "telephone,"—transmission being by sound, and not by writing, as in the common method. Important practical results may come from this invention, which Prof. Bell and his associate, Mr. Watson, are perfecting for general use. But some of the possibilities of it are rather startling. A stump-speaker, by this method, could perhaps be heard, on the same day, in all the cities and villages of the United States, so that a half-dozen campaign speakers would be enough for the new presidential election. . . . Again, by an instrument skillfully arranged, all the music of a prima donna could be distributed over the country while she was singing, thus popularizing good music to an extent as yet unknown. The Metropolitan newspapers could employ persons to read their articles to subscribers in distant parts, so that the expense of printing and mailing copies would be no longer necessary. By a judicious distribution of instruments, a whole parish might hear its minister preach on a stormy Sunday, without his leaving his study. . . . Wonderful are the achievements of science, by which the filing of a saw, or the flute-playing of an amateur, may be heard round the world like the morning drumbeat of the British army, or the shot fired at Concord Bridge.

It is interesting to note that the prophecies that a speaker might some day be heard in all the cities of the United States, and that the music of a prima donna could be distributed over the country, have been realized, in recent years, by means of instrumentalities unknown and undreamt of at the time when this article was written.

New York Sun, February 20, 1877

The following remarks were extracted from an article recounting an interview of a *Sun* reporter with Thomas A. Watson, Alexander Graham Bell's assistant:

"I haven't the slightest doubt," Mr. Watson said today, "that in a few months things will be so that a man may make a lecture here in Boston and be heard by an audience in any part of the country. . . . A company is now forming for the purpose of manufacturing and introducing the

instrument. . . . We expect, at first, it will be used mostly on private lines and for city business. . . ."

Apropos to singing by telegraph, I asked if it would not save a good deal of expense to our American opera managers. "An American audience could hear Nilsson, Patti, or any European prima donna, without bringing them across the Atlantic," I suggested. "Just place the receiving machine in the Boston Music Hall, for instance, and let the songstress put her mouth close to the mouthpiece in Paris, London, Vienna or St. Petersburg, and the effect would be the same as if the prima donna herself were present in the flesh."

"Certainly," said Mr. Watson, smiling, "and it would be curious to observe what effect the presence of the voice and absence of the person would have on the critics. Homely singers would probably advance in public esteem, while some of the beautiful cantatrices might suffer a corresponding set-back when their voices were judged on their merits."

No trial has been made, however, of the transmission of sounds to so great a distance as across the Atlantic. Mr. Watson said that as far as they had been able to ascertain, there seemed to be a limit to the distance over which the sounds could be made to travel; but he expressed himself as confident that in due time any given distance could be annihilated.

Boston Herald, February 24, 1877

The following extract is from a news account of Professor Bell's lecture and demonstration at Lyceum Hall, Salem, Mass.:

The lecturer then proceeded to mention some of the advantages which would be gained in the event of the general adoption of the telephone, by transmitting messages, such as making business arrangements, calling the doctor, and ordering a dinner and the like, without leaving home.

Providence Daily Journal, March 15, 1877

It is not improbable that methods will be found of reinforcing the sound transmitted so that the voice at the end of the journey may be louder than the original spoken words. The principle of the relay may also be applied to the telephone, so that the words whispered into the telephone ear at Boston may be repeated at the same instant in a hundred cities! When some future President is inaugurated, may not his words be caught by a telephonic ear, and be repeated to listening audiences all over the land?

Although intensive work was carried on, almost from the invention of the telephone, in the attempt to devise telephone relays or repeaters, several decades had elapsed before a commercially practical amplifying device was developed.

Lowell, Mass., Citizen, April 26, 1877 (Editorial)

Professor Bell believes that in the near future a central telephone office will be established in all our cities, with which the police, the fire department, most business houses and many private residences will have connections. When this is done any person having the connection can call the police, report a fire, order a dinner or chat with a neighbor without leaving the room.

This is believed to be the first editorial reference to a telephone central office. It does not, however, mark the inception of the idea in Bell's mind, as is shown by the following extracts from a letter which he wrote at a later date:

The idea of an Exchange Telephone system was one of the earliest conceptions, in connection with the possible use to which the telephone could be put. I discussed it with my associates, Mr. Hubbard and Mr. Sanders, long before the date of the Centennial Exposition in 1876. . . .

While therefore the idea was original with myself the execution of it has been due to others. I have no doubt that others also may have independently reached the conception, for . . . telegraphic exchanges of various kinds were already in existence at the time the telephone was first made known to the public. . . .

I do not know of my own knowledge to whom we are indebted for the first telephone exchange, but this I do know, that my conception of it antedates that of all others, because it goes back to the very inception of the telephone itself before it was made known to others.

For the sake of the record, it may be stated here that the first commercial telephone exchange was opened for service in New Haven, Conn., on January 28, 1878, by George W. Coy.

Springfield Republican, May 14, 1877

We have grown so used to new and marvelous additions to the power of telegraphy that nothing seems impossible, and Prof. Bell's confident

expectation that he will shortly be able to send his voice across the Atlantic and talk with men 3,000 miles away as readily as if they were in the next room, meets with no such incredulous and satiric hearing as Cyrus W. Field's first proposal to lay an ocean cable 20 years ago. Our discoveries in managing the powers of nature are indeed so rapid and continuous that miracles have fairly become commonplace. . . .

The practical uses of the invention are suggesting themselves already. Whether the transmission of music will ever be more than a matter of curiosity it is not necessary to consider. But that the conversational capacities of the telephone are, even in its present imperfect condition, equal to genuine usefulness, seems obvious. Among the purposes to which it will be applied first are for conveying intelligence in mines, which is already under consideration; communicating from one office with a large number of factories, for which a prominent New England manufacturer intends to utilize it as soon as may be; and for the benefit of divers beneath the ocean.

It does not seem likely that Professor Bell had, at that time, any immediate expectation of talking over the Atlantic cable. Whether he did or not, it was soon discovered that telegraph cables, whether on land or under water, were entirely unsuited to the transmission of speech. It is only in recent years that the telephone art has advanced to the point where it is possible to talk a distance of 3,000 miles over a specially designed telephone cable, equipped with amplifying devices.

With regard to the statement that "our discoveries in managing the powers of nature are indeed so rapid and continuous that miracles have fairly become commonplace," it may be noted that at the time those words were written there was no electric light, no electric railway, no phonograph, no motion picture, no automobile, no X-ray, no skyscraper, no radio and no airplane.

New York Times, May 20, 1877

The last of these newspaper quotations is from an account of Professor Bell's lecture in Chickering Hall, New York City:

Then the Professor went on with his explanation. He intimated that the telephone might be put to a "flood" of uses, only a few of which time

would allow him to name. A business man of New York, for instance, writes to his correspondent in Boston to meet him at the telephone office at a certain hour. The telephone office in each city consists of a series of little rooms with telephones in them. The two merchants enter corresponding rooms at the hour named, and locking the doors converse at their ease. They may shout as loud as they please and nobody else will hear them. Again, it is a rainy morning, and Mrs. Smith does not want to get wet. She calls on the central office to connect her with Mr. Jones, the butcher. It is done, and she orders her meats for dinner. Or she is lonely of an afternoon, and the central office man having, by her request, joined her wire with Mrs. Brown's, the two spend an hour very enjoyably in cutting up Mrs. Robinson. So with offices and houses, or workshops, and many other things. Its possibilities may be enlarged upon indefinitely.

It is a fact that when the commercial long distance telephone business was started, in the middle 80's, it was necessary for users of that service to go to the company's office to make their calls, on account of the unsuitability of subscribers' lines for long distance talking. It was not the practice, however, to write a letter in advance, and there is no record that the talkers found it necessary to lock the doors.

It will be noticed that the central office operator of the future is referred to as a "man." None of these early prophets —not even the inventor of the telephone himself—envisioned the fact, later proved by experience, that men and boys were temperamentally unsuited to the exacting duties of switchboard operation, and that this work was destined to be performed by members of the opposite sex.

The final quotation is from the *Operator*, a telegraph journal, which afterward became the *Electrical World*, and the reader will detect a certain amount of exaggeration, and perhaps the willingness, on the part of the author, to "take his readers for a ride." To appreciate properly this glowing tribute to scientific achievement, it is necessary to know that the invention of the microphone, or loose-contact transmitter, resulting from the work of Hughes, Berliner and Edison, had

been announced to the scientific world during the preceding month:

Operator, June 15, 1878

The veracious man of science tells us that, by the aid of the microphone . . . we may hear the prancing of a fly on a metallic disk with all the distinctness of a horse cantering over a bridge. Even the insect's respiration may be clearly heard, like the wheezing of an asthmatic elephant. Soon we can bring appliances to bear to gather up the minutest sounds, magnify them to a tremendous volume, and hurl them to any desirable distance. We are assured that we shall be able, not only to listen to the tramp of the tiniest insects, but to hear the growing of the grass, and the ripple of the sap ascending beneath the bark of the tree. The seething of the magic alchemy in the laboratory of the leaves, as they transmute the grossness of earth and air into forms of beauty, and the bravery of the summer's green shall become as audible as the clatter of a common workshop. Then will the dreaming poet, as he lays him down in the woods or field to feel the thrill of nature's voices, surround himself with batteries, disks, and wires, and bring to his ears the clash and roll, the hum, the ripple, and the clang of a Titanic orchestra. Nor will it be necessary to go to the fields and subject one's self to the depredations of bugs and ants to get all the benefit of the magnified and multitudinous sounds that keep the atmosphere vibrating. They may be gathered from their haunts in field and by brook, amid the gloom of forests and along the sounding shore, and be brought by wire from every direction to some grand hall in the busiest metropolis, and there let loose for the edification of gathered crowds. Perchance instruments may be devised whereby these myriad notes may be commingled and controlled to the utterance of most excellent music. Who knows but even the music of the spheres, the voice of the smallest star dust that

" in his motion like an angel sings
Still quiring to the young eyed cherubins,"

may be made perceptible to mortal hearing. The voices of earth and heaven may perchance unite in one tremendous symphony through the agency of the symphone that is yet to be invented.

But there are other possibilities hardly less interesting. Not every sound, whether of nature or of art, is either soothing or exhilarating. The nerves of man are subject to torture as well as exaltation. It is not given to all persons to be gently " Hushed with buzzing night-flies to the

slumber"; and to some the shrill clarion of the mosquito on his midnight marauding is anything but soothing. Cats that make night hideous with their private wrangles, and cackling poultry that spoil the morning nap, these utter sounds that no one would wish to have magnified. And although there might be a cacophone devised as an instrument of torture, to be used, perhaps, as a means of punishment for the worst class of criminals, as something more terror-striking than death itself, yet the virtuous and humane would be concerned for some apparatus that would utterly destroy and nullify horrid and disturbing sounds. Why cannot ingenuity apply itself to discovering some means for eliminating the sound waves from the air at will, so that the cat on the back fence, with arched back and tail erect, may be "seen and not heard," and the mosquito quench his raging thirst for gore without exasperating the victim with his whining, sniveling outcries? And while the combined telephone and microphone might, in the household, enable one to gather up most interesting whisperings, and accurately gauge the pulsations of two hearts that beat as one, it would be a peculiarly precious boon to be able to sit in one's office all unconscious of outer sounds. The strident and indirect upbraidings of the mother-in-law, the peevish cry of other people's children, the brawl of beggarly passers-by, the din of hand-organ in the street or piano in the adjacent boarding house, and all the distracting noises that make life weary . . . might be smothered by a faithful antiphone of some sort, whose function it should be to take the life out of every intruding sound. But no volume of moderate compass would suffice for the setting forth of all the possible results of the invention of phones and their application to the manipulation of sounds. We can only give the imagination a hint, and let it work in this most fascinating field, and meantime we must await the slow processes of invention before a full realization of the benefits of the latest uses of electricity.

The reader's first reaction to this highly imaginative article —which was unsigned—will probably be one of bafflement. All of the predictions set forth in the preceding pages have been realized, or are capable of realization. Here we have prophecies and desires which remain unfulfilled, after a lapse of nearly sixty years. Although it is possible to detect extremely minute sounds, there is no record that any human ear has heard the respiration of an insect, the growing of the grass, or the ripple of the sap ascending beneath the bark of a tree.

No "symphone" has been invented to unite the voices of earth and heaven in one tremendous symphony. There is as yet no "cacophone," for which we should be thankful. Had such a fiendish instrument appeared prior to the presentation of the "Mikado," its inventor would surely have been down on the list of persons who never would be missed. And no "anti-phone" has been devised to completely eliminate from the air itself all horrid and disturbing sound waves.

With regard to the "symphone," however, it is safe to say that the anonymous author who facetiously predicted its arrival would have been greatly astonished had he been in Constitution Hall, Washington, on April 27, 1933, and heard the perfect transmission and reproduction of symphonic music, played in Philadelphia, with the illusion of hearing each separate instrument from its proper position on the stage.

And as for the "anti-phone," although its full requirements have not been realized as yet, nevertheless, practical means, in the way of filters, have been devised for reducing the potency of unpleasant sounds, under certain conditions, and, if it is any comfort to the sufferer, the modern sound engineer can measure the magnitudes of these offending noises, and express them in decibels.

R. B. Hill

Notes on Recent Occurrences

OVERSEAS SERVICE EXTENDED TO PUERTO RICO AND KINGSTON

BELL System overseas telephone service has been further extended in the West Indies with the establishment of radio telephone circuits between the mainland of this country and the islands of Puerto Rico and Jamaica. Service to the former was opened on February 20, and to the city of Kingston, Jamaica, on April 3.

The service with Puerto Rico was inaugurated by an exchange of greetings between Secretary of the Interior Harold L. Ickes, in Washington, and General Blanton Winship, Governor of the island, in San Juan. Others taking part in the inaugural ceremonies included Chairman Anning S. Prall of the Federal Communications Commission, and officials of the Department of the Interior. K. S. McHugh, Assistant Vice President of the American Telephone and Telegraph Company, acted as master of ceremonies.

Those participating in the ceremonies at the New York end of the Kingston circuit were Sir Gerald Campbell, British Consul General; Richard W. Lawrence, Chairman of the Executive Committee of the New York Chamber of Commerce; and T. G. Miller, Vice President, Long Lines Department, American Telephone and Telegraph Company. Speaking from Kingston were Sir Edward Brandis Denham, Governor of Jamaica; George Armstrong, United States Consul; Ellis Levy, President, Jamaica Chamber of Commerce; Lewis Ashenheim, Chairman, Jamaica Telephone Company; and A. G. Blackwell, Manager, Direct West Indies Cable Company.

The telephone link between Puerto Rico and the mainland

consists of a short wave channel between the radio telephone stations of the Bell System at Miami now handling service to South and Central America and other West Indian islands, and stations of the Porto Rican Telephone Company, near San Juan. The same stations in Miami, working with stations of the Direct West Indies Cable Company at Kingston, provide the link between Jamaica and the mainland. The charge for a call between New York and either island is $18 for the first three minutes and $6 for each additional minute.

DR. FRANK B. JEWETT IS AWARDED FRANKLIN MEDAL

THE Franklin Institute of the State of Pennsylvania has announced the award of the Franklin Medal this year to Dr. Frank B. Jewett, President of the Bell Telephone Laboratories, Inc., and Vice President of the American Telephone and Telegraph Company. The presentation of the gold medal and certificate will be made on May 20 in the Hall of The Franklin Institute in Philadelphia at formal exercises presided over by President Nathan Hayward of the Institute.

The Franklin Medal is awarded annually from the Franklin Medal Fund, founded January 1, 1914, "to those workers in physical science or technology, without regard to country, whose efforts, in the opinion of the Institute, acting through its Committee on Science and the Arts, have done most to advance a knowledge of physical science or its applications." Dr. Jewett will receive the Medal "in recognition of his many important contributions to the art of telephony, which have made conversation possible not only from coast to coast, but from this country to the other side of the world—contributions of which some were made by him alone, and some by him in collaboration with other workers in the great laboratory of research which he organized and which he has directed with such signal success."

A similar medal will be awarded at the same ceremonies to Dr. Charles F. Kettering, General Director of the General Motors Research Laboratories and Vice President of the General Motors Corporation, Detroit, Mich. The late Gen. J. J. Carty, former Vice President and Chief Engineer of the A. T. & T. Co., was a recipient of the Franklin Medal in 1916. Other distinguished scientists who have been the recipients of the Franklin Medal during recent years are: Sir William Henry Bragg, Dr. John F. Stevens, Sir James H. Jeans, Dr. Willis R. Whitney, Prof. Philipp Lenard, Dr. Ambrose Swasey, Dr. Paul Sabatier, Dr. Orville Wright, Dr. Henry Norris Russell, Dr. Irving Langmuir, Dr. Albert Einstein, and Sir John Ambrose Fleming.

RADIO ENGINEERS HONOR DR. CAMPBELL

DR. GEORGE A. CAMPBELL, for many years a prominent member of the Bell System's scientific and engineering staff until his recent retirement, was awarded the Medal of Honor of the Institute of Radio Engineers by vote of the Board of Directors of that organization at a meeting held on April 1.

The medal was established in 1917 and is the senior medal awarded by the Institute. It is awarded annually in recognition of noteworthy inventions and developments in the electrical communication art. It is not given solely for any specific achievement in the radio field, but rather to recognize a number of contributions, extending over a lifetime. In Dr. Campbell's case, one of the factors which determined his selection for the honor was the contribution he has made to the theory of electrical networks. This theory finds application in the loading coils and wave filters used extensively in telephony.

Those who have received the award in the past include a number of European and American scientists whose names

stand high in the field of electrical communication. These include: E. H. Armstrong, E. F. W. Alexanderson, G. Marconi, R. A. Fessenden, Lee de Forest, John Stone Stone, M. I. Pupin, G. W. Pickard, L. W. Austin, Jonathan Zenneck, G. W. Pierce, P. O. Pedersen, G. A. Ferrie, A. E. Kennelly, J. A. Fleming, S. C. Hooper and B. van der Pol.

Formal presentation of the medal will take place at the Eleventh Annual Banquet of the Institute, at the Hotel Statler, Cleveland, O., on May 12.